W. B. Mack

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CONSTITUTION*

ARTICLE I

The name of this Association shall be the American Society for Horticultural Science.

ARTICLE II

The object of the Society shall be to promote the Science of Horticulture.

ARTICLE III

Voting members: Any person who has a baccalaureate degree and holds an official position in any agricultural college, experiment station, or federal or state department of agriculture in the United States or Canada, is eligible to membership. Other applicants may be admitted by vote of the executive committee.

Associate Members: Any person not eligible to voting membership will be eligible to associate membership upon vote of the executive committee. Associate members shall not vote and will present papers only at the request of the program committee.

ARTICLE IV

Meetings shall be held annually at such time and place as may be designated by the Executive Committee, unless otherwise ordered by the Society.

ARTICLE V

The officers shall consist of a President, a Vice-President, a Secretary-Treasurer, and sectional chairmen to represent the subject-matter sections of the Society.

ARTICLE VI

The Constitution may be amended by a two-thirds vote of the Society at any regular meeting, notice of such amendment having been read at the last regular meeting.

BY-LAWS*

Section 1—*Duties of Officers:* The President shall preside at business meetings and general sessions of the society, deliver an address at the regular annual meeting, and serve ex officio as a member of the executive committee.

The Vice-President shall preside at business meetings and general sessions of the Society in the absence of the President and serve ex officio as a member of the executive committee.

The Sectional Chairmen shall preside at sectional meetings and serve ex officio as members of the executive committee.

The Secretary-Treasurer shall keep the records of the Society; edit, publish, and distribute the Proceedings and other publications; mail to members a call for papers for the annual meeting at least 30 days prior to closing date for acceptance of papers, and at least 3 months prior to the annual meeting shall request of members suggestions regarding nominations, matters of policy and general welfare of the Society; serve ex officio as a member of the executive and program committees; collect dues from members; and conduct the financial affairs of the Society with the aid and advice of the chairman of the executive committee.

Section 2—*Executive Committee:* There shall be an executive committee consisting of the retiring President, who shall be chairman, the President, the Vice-President, the Sectional Chairmen, the chairmen of regional groups, the Secretary-Treasurer, and two members elected at large for terms of two years each, retiring in alternate years. This committee shall act for the Society in the interim between annual meetings; shall fix the date for the annual meeting; shall present at each annual meeting nominees for members of the nominating committee; shall act on admission of all associate members, regional groups and

*As revised and adopted at the Philadelphia meeting, January 1, 1941.

junior branches and in special cases may elect to voting membership persons of high qualifications but otherwise ineligible; shall consider matters of general policy or welfare of the organization and present its recommendations at the annual meeting of the Society.

Section 3—*Nominating Committee:* There shall be a committee on nominations consisting of two members from each of the sectional groups who shall be nominated by the executive committee and elected by ballot at each annual meeting of the Society. It shall be the duty of this committee, at the following annual meeting to present a list of nominees for the various offices, committees (except the Nominating Committee), representatives, and sectional chairmen who shall be selected after consultation with the sections. This committee shall also nominate referees and alternates upon special subjects of investigation or instruction which may be referred to it for consideration by this Society. The duties of these referees shall be to make concise reports upon recent investigations or methods of teaching in the subjects assigned to them and to report the present status of the same.

Section 4—*Program Committee:* There shall be a committee on program, consisting of five (5) members, of which the secretary shall be one. This committee shall have charge of the scientific activities of the Society, except as otherwise ordered by the Society. It shall receive titles and arrange the program of the annual meeting; arrange symposia; accept or reject titles, and may invite non-members to participate.

Section 5—*Editorial Committee:*—There shall be an Editorial Committee consisting of five members. One member shall be elected each year to serve for five years. It shall be the duty of this committee to formulate the editorial and publication policies of the Society; to assist the Secretary in reviewing and editing papers and shall have final authority to reject any paper deemed not worthy or unsuitable for publication in the Proceedings.

Section 6—*Membership Committee:* There shall be a committee on membership whose duties shall be the promotion of membership in the Society.

Section 7—*Auditing Committee:* There shall be a committee to audit the books of the Society and report their condition at each annual meeting.

Section 8—*Committee on Local Arrangements:* There shall be a committee on local arrangements who in cooperation with the Secretary-Treasurer will have charge of all local arrangements for the annual meeting.

Section 9—*Quorum:* Ten members of the Society shall constitute a quorum for the transaction of business at a regularly called meeting of which at least 30 days notice shall have been given to members.

Section 10—*Annual Dues:* The annual dues of the Society shall be five dollars.

Section 11—*Amendment to the By-Laws:* The by-laws may be amended at any regular meeting by a two-thirds vote of members present providing a copy of such amendment has been sent to all members at least 30 days prior to the meeting.

Section 12—*Regional Groups:* Upon the presentation of a petition signed by ten or more members of this Society residing within a stated region, the executive committee may approve the formation of a regional group affiliated with this Society. Such group must elect as a minimum number of officers a chairman, a vice-chairman and a secretary and shall present an annual report to the Secretary-Treasurer of the national Society to include the names of its officials and a review of its meetings or other activities. Publication of this report in full or in part shall be made in the Proceedings of this Society. Papers presented at regional group meetings may be published on the same basis as papers presented at the regular annual meeting.

Section 13—*Junior Branches:* A student horticultural group at a college or university, operating under the supervision of a member or members of this Society, may organize as a Junior Branch of the American Society for Horticultural Science upon approval of the executive committee and the payment of an annual fee of five dollars for the branch. Each branch shall receive a copy of all publications of the Society. Such a branch shall elect a chairman, a vice-chairman and a secretary-treasurer and shall present an annual report of its activities to the national Secretary-Treasurer. Such groups may hold meetings in conjunction with the annual meetings of this Society and a report of such meetings, not including individual papers, may be included in the Proceedings.

SOCIETY AFFAIRS

Treasurer's Report

Receipts

Dues (1943–1944)	$3,982.50		
Proceedings sold	2,694.26		
Reprints, etchings and extra pages	2,954.03		
Miscellaneous receipts	140.39		
		$9,771.18	
Interest on money in savings account		47.50	
Balance on hand December 30, 1943		6,156.87	
Bills receivable, outstanding accounts		323.33	
			$16,298.88

Expenditures

Printing Proceedings	$5,436.56		
Halftones and etchings	841.15		
Printing reprints	524.73		
Office supplies, printing envelopes, labels, etc.	138.70		
Printing programs	97.50		
Secretary's office	525.42		
Postage and express	274.22		
Proceedings purchased for resale	114.00		
Security bond	30.00		
Telegrams	3.64		
Bank charges	37.94		
Total expenditures		$8,023.86	
On hand December 20, 1944		7,951.69	
Bills receivable		323.33	
			$16,298.88

This is to certify that we have examined the books of the Treasurer of this Society and have found them in good order.

Auditing Committee
Roy E. Marshall, *Chairman*
A. J. Heinicke

Studies on Control of Magnesium Deficiency in New York Apple Orchards

By DAMON BOYNTON,[1] *Cornell University, Ithaca, N. Y.*

THIS paper summarizes work done on the control of magnesium deficiency in New York apple orchards during 1943 and 1944.

SOIL APPLICATIONS OF DOLOMITIC LIMESTONE AND EPSOM SALTS

In September, 1942, twenty pairs of trees showing the blotch symptom of magnesium deficiency were marked in a bearing Orange County McIntosh orchard and a like number were marked in a mature Wayne County McIntosh orchard. Both orchards carried moderate crops and were under good commercial care. Both trees of all pairs were similar in size, crop, and in the degree of development of the blotch symptoms.

In April, 1943, one tree of every pair was fertilized with 100 pounds of dolomitic limestone (25 per cent MgO). The sod was removed from a zone between 2 and 10 feet (approximately) from the trunk, the lime was broadcast in that area, spaded or hoed in, and the sod was replaced. In July, leaf samples were taken for chemical analysis. At that time, no symptoms of magnesium deficiency were apparent in either orchard. A separate sample of 30 leaves was taken from each experimental tree. The leaves were picked at random from median positions on current season's shoot growth. The samples were dried at 65 degrees F, ground to pass a 2-mm sieve, and were later analyzed by the quantitative method of Peech (3).

In mid-September, soon after harvest time, the trees were scored for development of magnesium deficiency blotch.

In April, 1944, the limestone applications were repeated in both orchards. When the lime was "dug" into the soil under the trees, some lumps and lenses of the lime that was applied in the previous year were found mixed with the surface soil of all treated trees. After the lime was applied, 10 pounds of epsom salts were broadcast under one-half of the limed trees in both experimental blocks. In July separate leaf samples were taken from all trees for chemical analysis. At that time, no magnesium deficiency symptoms were evident in either orchard. The leaf samples were prepared for analysis as in 1943 but the analyses were made by the rapid microchemical method of Peech and English (4) as adapted by Boynton and Peech (2). In mid-September, following harvest, the trees were scored for development of blotch.

Separate soil samples, composites of four California soil tube borings taken at about 6 feet from the trunks of the trees, were taken at two depths under all experimental trees in September, 1944. They were dried and passed through a 2-mm sieve. Determinations were

[1]The author acknowledges the help of J. D. VanGeluwe, former Assistant County Agent of Orange County, who made the spray applications both in 1943 and 1944.

made of pH using the glass electrode, and of estimated calcium and magnesium by the rapid microchemical methods of Peech and English (4).

Table I summarizes the data on leaf analysis and tree symptoms. In the Orange County orchard, dolomitic limestone increased leaf magnesium percentages slightly in the first year of treatment. The mean increase of Mg content was statistically significant only for the

TABLE I—LEAF ANALYSIS AND TREE SYMPTOMS

Year	Trees	Treatment	Leaf Mg† (Per Cent Dry Weight)	T Value	Trees Showing Blotch**		
					Moderate to Severe	Slight	None
		Paulhamus Orchard, Orange County					
1943	1-10L	Lime	.19		1	9	0
	1-10C	Ck	.18		2	7	1
		Mean difference	.01	0.5*			
	11-20L	Lime	.20		2	7	1
	11-20C	Ck	.17		8	1	1
		Mean difference	.03	3.8*			
1944	1-10L	Lime + epsom salts	.24		0	0	10
	1-10C	Ck	.16		0	4	6
		Mean difference	.08	5.3*			
	11-20L	Lime	.24		0	1	9
	11-20C	Ck	.16		1	5	4
		Mean difference	.08	3.6*			
		DeRight Orchard, Wayne County					
1943	1-10L	Lime	.12		0	3	7
	1-10C	Ck	.08		4	3	3
		Mean difference	.04	2.8*			
	11-20L	Lime	.11		0	4	6
	11-20C	Ck	.09		5	3	2
		Mean difference	.02	4.2*			
1944	1-10L	Lime + epsom salts	.27		0	0	10
	1-10C	Ck	.13		4	2	4
		Mean difference	.14	5.4*			
	11-20L	Lime	.24		0	0	10
	11-20C	Ck	.11		1	6	3
		Mean difference	.13	9.3*			

*T value of at least 2.8 is required for odds of 99:1 that a mean difference is not due to chance, by Student's method

**The trees were scored shortly after harvest in mid-September.

†Each leaf Mg figure is the mean of separate samples of 30 median shoot leaves taken in midsummer from each of 10 experimental trees.

second group of 10 trees. This slight increase in Mg content appeared to be associated with partial control of the development of blotch. Trees 1 to 10 whose mean leaf Mg was not increased significantly by liming showed practically no benefit from the treatment. In 1944, both the first group of trees (receiving lime plus epsom salts), and the second group of trees (receiving lime alone), showed greater increases of leaf Mg than in the previous year, and also showed almost complete absence of the symptom, whereas in 1943, 19 of the 20 treated trees had some blotch in September, only 1 had any in 1944.

Unfortunately, the check trees did not have as much blotch in 1944 as 1943; this was without doubt due to the very dry weather of the 1944 growing season, a condition that seems to inhibit the development of magnesium deficiency symptoms (1). However, half of the check trees were affected somewhat. There was no apparent benefit from the epsom salts in addition to lime.

In the Wayne County orchard, dolomitic limestone caused small but significant increases of leaf Mg in both groups of trees the first year of treatment. These increases of leaf Mg were associated with partial recovery from blotch. In 1944 both groups of trees receiving limestone showed greater increases of leaf Mg than in the previous year, and there seemed to be complete recovery from the blotch symptom; while the check trees did not show quite as much blotch as in the previous year, 13 of the 20 trees had some of the symptom. There was no measurable benefit from the epsom salts in addition to lime.

Table II presents data on the pH and estimated lime and magnesium contents of the soil at two depths under treated and untreated trees, after 2 years of liming. As might be expected, the heavy applications of dolomitic limestone resulted in marked increases of pH and in calcium and magnesium to a depth of a foot.

TABLE II—SOIL ACIDITY AND ESTIMATED CALCIUM AND MAGNESIUM CONTENTS IN SOILS UNDER LIMED AND UNLIMED TREES AFTER TWO YEARS OF LIMING

Trees	Treatment	2–6 Inch Depth*			8–12 Inch Depth*		
		pH**	Ca (Pounds)	Mg Per Acre	pH	Ca (Pounds)	Mg Per Acre
Paulhamius Orchard, Orange County (Dutchess Stony Loam)							
1-10L	Lime	5.93	4,155	564	5.13	1,255	212
1-10C	Ck	4.33	500	21	4.49	222	15
11-20L	Lime + epsom salts	5.95	3,240	375	5.33	1,060	176
11-20C	Ck	4.40	480	23	4 56	200	15
DeRight Orchard, Wayne County (Dunkirk Fine Sandy Loam)							
1-10L	Lime	6.26	1,950	398	5.23	530	111
1-10C	Ck	4 63	120	10	4.68	130	10
11-20L	Lime + epsom salts	6.38	3,275	315	5.61	545	101
11-20C	Ck	4.60	105	10	4.73	90	11

*Each figure is the mean of 10 determinations. All differences are highly significant statistically.
**The mean pH was calculated by averaging H ion concentrations and converting back to pH.

SPRAYS OF EPSOM SALTS AND HIGH MAGNESIUM HYDRATED LIME

In 1943 and 1944, spraying tests were conducted in a mature, Orange County Baldwin orchard which was badly affected with magnesium deficiency blotch in 1942 when it bore a heavy crop. Unfortunately, the orchard was barren both in 1943 and 1944, and practically no symptoms developed in either year.

Tables III and IV summarize the data on analysis of leaves from the spray plots for the two years. The analyses seem to indicate that

TABLE III—ANALYSES OF LEAVES FROM BALDWIN TREES IN RELATION TO MAGNESIUM SPRAYS APPLIED IN 1943

Treatment	Sample	Leaf Mg* (Per Cent Dry Weight)
Check for Epsom salts sprays	Composite 1–10**	0.17
	Composite 11–20	0.17
2 per cent Epson salts in regular cover sprays 1st and 3rd weeks of July	Composite 1-10	0.40†
	Composite 11-20	0.49†
Check for Mg lime sprays	Composite 1–10	0.17
	Composite 11–20	0.17
2 per cent high Mg spray lime in regular cover sprays 1st and 3rd weeks of July	Composite 1–10	0.38
	Composite 11–20	0.37

*Analysis by the quantitative procedure of Peech (3)
**Leaf samples taken Sep 13, 1943. Each composite was composed of 10 median shoot leaves per tree from 10 trees The leaves were wiped with wet cheesecloth to remove spray residue, soon after sampling.
†This treatment resulted in leaf injury similar in appearance to arsenical injury, and subsequent early dropping of 25 to 50 per cent of the leaves.

TABLE IV—ANALYSIS OF LEAVES FROM BALDWIN TREES IN RELATION TO MAGNESIUM SPRAYS APPLIED IN 1944

Treatment	Sample*	Leaf Mg (Per Cent Dry Weight**)
Check	Composite 1–5	0.15
	6–10	0.10
	11–15	0.10
	16–20	0.10
	Mean	0.11 ± 0.013†
1 separate spray of 1 per cent Epsom salts 3rd week of June	Composite 1–5	0.25
	6–10	0.20
	11-15	0.30
	16–20	0.20
	Mean	0.24 ± 0.024†
1 separate spray of 2 per cent Epsom salts 3rd week of June	Composite 1–5	0.20
	6–10	0.15
	11-15	0.30
	16–20	0.30
	Mean	0.24 ± 0.038†
2 separate sprays of 2 per cent Epsom salts 3rd week of June and 1st week of July	Composite 1–5	0.20
	6–10	0.20
	11-15	0.30
	16–20	0.20
	Mean	0.23 ± 0.025†
2 per cent Mg spray lime in regular cover sprays 3rd week of June and 1st week of July	Composite 1–5	0.35
	6–10	0.25
	11–15	0.25
	16-20	0.25
	Mean	0.28 ± 0.025†

*Leaf samples taken July 17, 1944. Each composite was composed of 20 median shoot leaves per tree from 5 trees. The leaves were wiped with clean wet cheese cloth to remove spray residue, soon after sampling.
**Analysis by the rapid microchemical procedure of Peech and English (4).
†Standard error.

two cover sprays including either epsom salts or high magnesium hydrated lime (30 per cent MgO) at 16 pounds to 100 gallons of water can increase the magnesium percentages in apple tree leaves. A pre-

vious study (1) indicated that four cover sprays of epsom salts at that concentration eliminated blotch on Mg deficient Cortland apple trees and built up leaf magnesium above 0.25 per cent of dry weight in the year of spraying.

In 1943 the epsom salts was added to the regular flotation sulphur and lead arsenate cover spray materials with 1 pound high calcium hydrated lime per pound of lead arsenate as a corrective for arsenical injury. A month after the last spray, marginal and tip burning of leaves, similar in appearance to arsenical injury, was evident on the trees to which epsom salts had been applied but not on the others. By harvest time, 25 to 30 per cent of the leaves had yellowed and dropped from the epsom salts-sprayed trees, whereas the others had no leaf drop. Evidently conditions in the orchard were particularly conducive to spray injury because 1943 and 1944 trials with these same mixtures in the Cornell University orchard on McIntosh, Baldwin, and R. I. Greening trees failed to produce visible injury.

In 1944, the epsom salts sprays were applied separately, and, as in the original experiment with Cortland trees (1), no spray injury resulted. There were no significant differences in leaf Mg between the trees receiving one spray of 1 per cent, one spray of 2 per cent, or two sprays of 2 per cent epsom salts; nor was there significance in the difference of magnesium percentage between the leaf samples from the Mg lime-sprayed trees and those receiving epsom salts. However, leaf samples from all of the Mg spray treatments appeared to differ significantly from the check samples.

Lacking data on recovery from leaf blotch, no conclusions on control of magnesium deficiency may be based on the experiments in spraying of Baldwins here reported. However, the leaf analyses indicated that two cover sprays including 16 pounds of high magnesium spray lime per 100 gallons in regular summer cover sprays, were as effective in increasing leaf magnesium as two sprays including 16 pounds of epsom salts.

It should be said that such a heavy dosage of spray lime makes a white deposit on leaves and young fruits, and may decrease the effectiveness of arsenicals.

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Further Data on Correcting Magnesium Deficiency in Apple Orchards

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IN PREVIOUS papers (5, 6), evidence of magnesium deficiency and some results in correcting it in Massachusetts apple orchards were presented. The present paper reports further data.

MATERIALS AND METHODS

Soil applications of magnesium compounds and sprays containing Epsom salts were used in several orchards. Effects of treatments were shown by subsequent scorch severity and chemical analysis of leaves. Much of the work was done in a 6-year-old orchard, described in a previous paper (5). Other older blocks at Amherst and a commercial orchard in Three Rivers were also utilized.

TREATMENTS AND RESULTS

SPRAYS

Experiment No. 1.—In 1943, a magnesium deficient experimental block of 6-year-old trees consisting of nine plots was divided into three sections and treated as follows: Section I — 146 trees received four special spray applications consisting of 16 pounds of Epsom salts in 100 gallons of water on May 13, May 25, June 4, and June 16. In 1944, magnesium was applied to these trees by adding 20 pounds of Epsom salts to each 100 gallons of regular spray solution in the calyx (May 17), first cover (May 25), and second cover (June 7) applications. Section II — 146 trees received only the two earlier special spray applications in 1943 (May 13 and May 25). In 1944, the treatment was the same as for section I. Section III — check — no magnesium was applied in sprays except for the small amount contained in the hydrated lime which was used in several applications on all of the trees.

The amount of spray applied varied from one to two gallons per tree depending largely on size. There were no observable deleterious effects from adding the Epsom salts to the well-agitated wettable sulfur-lead arsenate-hydrated lime spray mixture. It should be pointed out here that each plot contains several varieties worked on several rootstocks randomized for both stock and variety and that the same combinations are present in each plot. There was some loss of trees due to wind damage prior to the 1944 sampling. Table I sums up the pertinent data from this experiment.

It is apparent that the magnesium applied in the early-season sprays was sufficiently effective in correcting the magnesium deficiency condition to markedly reduce the severity of leaf scorch, which is one of the most obvious symptoms of the deficiency on apple trees. Whereas the trees in section I were on the average the most severely scorched

[1]Contribution No. 588 from the Massachusetts Agricultural Experiment Station.

TABLE I—TREATMENT, MAGNESIUM DEFICIENCY LEAF SCORCH, AND LEAF ANALYSIS ORCHARD B-1, MASSACHUSETTS STATE COLLEGE

Mg Spray Treatment (No. and Year of Applications)	Trees Showing Medium to Severe Scorch, Aug. 1942 (Per Cent)	Trees Showing Various Amounts of Leaf Scorch, Sep. 1944 (Per Cent)				Total No. Trees (Sep 1944)	Leaf Analysis Aug. 1944* Per Cent of Dry Weight		
		0-Trace	Light	Medium	Severe		Mg	K	Ca
				Section I					
4 in 1943 3 in 1944	62	99	1	0	0	139	0.26	2.17	1.17
				Section II					
2 in 1943 3 in 1944	47	85	15	0	0	134	0.23	2.13	1.01
				Section III					
Check	45	54	29	12	5	136	0.19	2.19	1.26

*One leaf per tree in each sample.

in 1942, only one per cent showed more than a trace of scorch in 1944. In contrast, the check trees, which were not as badly affected in 1942 before the start of differential treatments, showed 29 per cent light scorch and 17 per cent medium-to-severe scorch in 1944. The trees in section II assume an intermediate position. Considering the leaf analysis data for magnesium, there seems to be a good correlation between the amount of magnesium found in the leaves (per cent of dry weight) and the amount or severity of scorch. It should be noted that a sample for analysis consisted of one leaf from each tree in a section. In each case, the leaf was taken from approximately the same position on current shoot growths. Also, it should be stated that small amounts of magnesium were supplied by the hydrated lime used as a "safener" in several of the spray applications. However, since this treatment was uniform over the entire orchard, the significance of the comparative differences described above as due to the inclusion of Epsom salts in the sprays is not disturbed. Good results from spraying moderately deficient older trees have been reported by Boynton *et al.* in New York (1).

SOIL

Experiment No. 1.—The first year's results from this experiment were reported previously (6). Detailed description of the setup will not be repeated. Briefly, in late September, 1942, soil applications were made as follows: 5 pounds of magnesium oxide, 5 pounds of Epsom salts, or 25 pounds of commercial dolomite (magnesium limestone) per tree. A record of leaf scorch has been made each year and in September, 1944, leaf samples were taken. The orchard was six years old. The data are given in Table II.

In 1942, magnesium deficiency leaf scorch was more prevalent and severe in orchards at Amherst than in any other year. Scorch developed markedly from the middle of August to the middle of September in 1942 as shown in the table.

On the basis of the percentage of magnesium in the leaf dry matter in 1944, the magnesium oxide treatment has been the most effective.

TABLE II—TREATMENTS, MAGNESIUM DEFICIENCY LEAF SCORCH, AND LEAF ANALYSIS ORCHARD B-2, MASSACHUSETTS STATE COLLEGE

Plot	No. of Trees	Treatment Sep. 1942 (Soil Applications per Tree**)	Approximate Trees With More Than a Trace of Scorch (Per Cent)					Leaf Analysis (Sep. 1944)* Per Cent of Dry Weight			Per Cent of Ash as MgO
			Sep 1941	Aug 1942	Sep 1942	Sep 1943	Sep 1944	Mg	K	Ca	
2	20	5 pounds magnesium oxide	65	63	92	2	5	0.39	1.83	0.98	10.74
7	20	5 pounds magnesium oxide						0.38	1.61	1.27	9.69
3	20	5 pounds Epsom salts	55	58	90	2	3	0.29	1.91	1.21	7.59
6	20	5 pounds Epsom salts						0.31	1.97	1.12	8.13
4	20	25 pounds dolomite	35	50	82	42	13	0.25	2.11	1.13	6.41
5	20	25 pounds dolomite						0.26	1.94	1.47	6.24
1	20	Check	35	38	85	22	18	0.23	1.79	1.40	5.92
8	20	Check						0.24	1.95	1.24	5.82

*Six leaves per tree in each sample
**Commercial Dolomite (Magnesium Limestone)—20 per cent MgO.
Epsom Salts ($MgSO_4 \cdot 7H_2O$)—16.3 per cent MgO.
Magnesium Oxide—92 per cent MgO.

The Epsom salts applications have also increased the magnesium intake by the trees and as far as visible leaf scorch symptoms are concerned, there has been little, if any difference, between these two treatments. The dolomite applications thus far have resulted in only slight increases of magnesium in the leaves.

It will be noted that the check trees have been less severely scorched in the last two years. The reasons for this trend are not entirely clear but it is believed that climatic factors have been instrumental. Conditions in 1942 were evidently more favorable for the development of serious magnesium deficiency leaf scorch at Amherst than subsequently. Secondly, tree applications of muriate of potash and nitrate of soda have not been made since 1941. Thirdly, approximately one ton of commercial dolomite per acre was broadcast in 1942 and 1943 throughout the entire orchard on the sod strips between the tree rows. It is possible that some benefit from this magnesium has accrued. And finally, it may be that sufficient magnesium was supplied from the hydrated lime used in several of the spray applications as a "safener" to be somewhat beneficial. The hydrated lime used in 1944 contained magnesium equivalent to 2.7 per cent MgO.

Experiment No. 2A.—Thirteen magnesium deficient trees (five varieties) scattered in guard rows in an Experiment Station orchard (set in 1938) were given a soil dressing of five pounds of calcined kieserite (30 per cent MgO) on August 11, 1942. This was dug into the soil to some extent. One or more trees were chosen as checks for each of the 13 treated trees. In each comparison, the severity of scorch in 1942 was equivalent on treated and check trees. Table III summarizes the leaf scorch situation in 1944, two years after the treatments. In brief, the data seem to show that the kieserite applications have been beneficial although a complete cure of the magnesium deficiency was not obtained.

Experiment No. 3A.—A small experiment was begun in a block of 4-year-old McIntosh trees in October, 1942, when Epsom salts and

TABLE III—EFFECT OF KIESERITE APPLICATIONS IN 1942 ON DEVELOPMENT OF MAGNESIUM DEFICIENCY LEAF SCORCH IN 1944 (13 COMPARISONS)

Treatment	Percentages of Trees in Various Leaf Scorch Classifications			
	No Scorch	Trace	Light	Medium
Kieserite—5 pounds per tree	23	54	23	0
Check	0	39	54	7

commercial dolomite were applied on the surface of hay mulch under the trees. Five pounds of Epsom salts and/or 25 pounds of dolomite were used per tree. These applications were repeated on half of the treated trees in May, 1943. Table IV gives the data for this experiment.

TABLE IV—TREATMENTS AND LEAF ANALYSIS ORCHARD B-3, MASSACHUSETTS STATE COLLEGE

Treatment**	No. of Trees Per Treatment	Leaf Analyses—1944 (Per Cent of Dry Weight)		
		Magnesium	Potassium	Calcium
Epsom salts 1942	6	0.25	1 56	1.00
Epsom salts 1943	8	0 27	1 80	1.09
Epsom salts 1942 and 1943	6	0 32	1.26	1 05
Epsom salts + dolomite 1942	6	0.32	1 71	1.16
Epsom salts + dolomite 1942 and 1943	6	0 32	1 69	1.08
Check	8	0.18	1.84	1.29

**Epsom salts—5 pounds per tree.
Commercial dolomite (magnesium limestone)—25 pounds per tree

All of the treatments increased the magnesium in the leaves to above the minimum amount deemed necessary according to previous studies (5). Two applications seemed more effective than single applications although the differences are not great. It is interesting to note that there is some evidence of the effectiveness of dolomitic limestone. For example, in the 1942 treatments of Epsom salts with and without commercial dolomite, the respective figures for percentage of magnesium in the leaf dry matter are 0.32 and 0.25.

Experiment No. 4.—This large test of soil applications in a mature commercial orchard in Three Rivers, Massachusetts, has been described in an earlier report (6). Treatments were given on September 2, 1942. Table V gives the data of this test. The leaf samples for analysis were taken each year in September.

As shown in the table, there has been little benefit from most of the treatments. The largest increase in the percentage of magnesium in leaf tissue from 1942 to 1944 was 0.13 in a 10-pound Epsom salts treatment. Most of the trees were scorched almost as badly in 1943 and 1944 as previously.

Prior to 1942, fairly liberal fertilization with potash was followed, accounting for the rather high amounts of potassium found in the leaves in 1942. There has been no potash used since, and this fact is reflected in the steadily decreasing values for potassium from 1942 to 1944. It is known that potash fertilization tends to increase magnesium

TABLE V—TREATMENTS AND LEAF ANALYSIS FROM INDIVIDUAL TREES WHICH SHOWED MEDIUM-TO-SEVERE LEAF SCORCH IN 1942 (THREE RIVERS, MASS.)

Treatment (Sep 2, 1942) (Soil Applications Broadcast Unless Otherwise Stated)**	Leaf Analyses* Per Cent of Dry Weight						Mg Increase 1942–1944
	1942		1943		1944		
	Mg	K	Mg	K	Mg	K	
Section I, Baldwin Variety							
Check	0.12	2.53	0.10	2.28	0.13	1.79	0.01
50 pounds dolomite	0.14	2.07	0.11	1.97	0.18	1.44	0.04
10 pounds kieserite	0.16	2 42	0.14	1.77	0.23	1.46	0.07
10 pounds Epsom salts (ring)	0.14	2.29	0.16	1.64	0.18	1.46	0.04
Section II, McIntosh Variety							
Check	0.13	1.60	0.16	1.70	0.15	1.39	0.02
50 pounds dolomite	0.11	1.91	0.15	1.52	0.19	1.34	0.08
5 pounds Epsom salts (ring)	0.12	1.68	0.11	1.88	0.15	1.57	0.03
10 pounds Epsom salts (ring)	0.10	1.93	0 11	1.73	0.15	1.49	0.04
10 pounds Epsom salts	0.10	2.19	0.19	1.69	0.23	1.45	0.13
Section III, McIntosh Variety							
Check	0.13	2 01	0.13	1.48	0.15	1.29	0.02
10 pounds Epsom salts (ring)	0.12	1.87	0.11	1.53	0.14	1.26	0.02
10 pounds Epsom salts	0.10	2.19	0.12	1.74	0.14	1.37	0.04

*125 leaves per sample.
**Commercial dolomite (magnesium limestone)—20 per cent MgO.
Kieserite ($MgSO_4 \cdot H_2O$)—30 per cent MgO.
Epsom salts ($MgSO_4 \cdot 7H_2O$)—16.3 per cent MgO.

deficiency symptoms in apple trees and these data indicate that in any such situation, omission of potash for several years on a light soil may bring the level down considerably within a relatively short period.

DISCUSSION

It is recognized, of course, that the best treatment for magnesium deficiency is the supplying of magnesium rather than the omission from the fertilizer program of some other nutrient element, such as potassium. This emphasizes the value of applying magnesium in the regular sprays early in the season because of the immediate benefit in contrast to the somewhat delayed results expected from soil applications. In any orchard, however, in localities known to possess low supplies of soil magnesium it seems that commercial dolomite applications may well be made, provided such treatments will not produce a soil pH substantially above 6.5. Such applications eventually should help to effect a permanent cure in affected orchards and may well forestall and prevent the appearance of the trouble in orchards not yet showing visible deficiency symptoms. Somewhat delayed and variable responses from dolomite applications have been reported in New Zealand but in some instances good results were secured (4).

In young, and particularly in mulched orchards, soil applications of various magnesium compounds may be expected to be rather quickly effective. The use of commercial magnesium oxide seems to be particularly promising. Even when used at the same rate as Epsom salts, the

L.D. Doneen, 1972

cost is moderate. Also, this material has more than twice the neutralizing value of limestone. Furthermore, the data show that as a surface application, magnesium oxide seems to be much more effective than dolomite (on equivalent MgO basis) in supplying magnesium to apple trees. A possible explanation is that the presence of the calcium in the dolomite inhibits the intake of the magnesium by the tree roots. Eisenmenger and Kucinski reported that on a magnesium deficient soil at Amherst, "when magnesium and calcium are added to the soil together, the intake of both elements may be decreased" (3). Analyses of leaves selected in 1943 by the senior writer from small apple trees growing on these long-time plots may substantiate this statement. Leaves from untreated trees gave 0.13 per cent Mg in the leaf dry matter; from those receiving Epsom salts, 0.23 per cent; Epsom salts plus calcium limestone, 0.17 per cent; and limestone alone, 0.16 per cent. If this is true, then calcium limestone applications may under some conditions increase or even induce magnesium deficiency in fruit trees, due perhaps to a widening of the ratio between calcium and magnesium in the soil (2).

Summary

Data are presented on the corrective effects of spray and soil applications of magnesium on magnesium deficient apple trees. The effects of treatments were determined on the bases of foliage scorch and percentages of magnesium in leaf dry matter before and after treatments, the time intervals being either one or two years.

The inclusion of 20 pounds of Epsom salts per 100 gallons of spray solution in three early-season applications was rather effective in preventing the appearance of magnesium deficiency leaf scorch in the year of application. This treatment seems especially valuable for trees which may be slow in responding to soil applications of magnesium materials. As a temporary measure for controlling scorch, it has a definite place particularly in mature orchards.

Soil applications of Epsom salts and kieserite were beneficial in young mulched blocks, but one application of dolomite, kieserite, or Epsom salts was substantially ineffective in a seriously deficient bearing orchard under sod culture. The application of commercial magnesium oxide (92 per cent MgO) appeared to result in greater increases of magnesium in apple leaves on young trees than the use of Epsom salts applied in similar amounts by weight. Results with magnesium oxide on older trees have not been obtained. Commercial dolomite (magnesium limestone) has seemed to be less beneficial than other materials, even when used in relatively large amounts, unless the dolomite was applied along with Epsom salts.

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Magnesium Deficiency in Maine Apple Orchards

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Magnesium deficiency has been observed in Maine orchards during the past ten years or more. Until recently it was referred to as "Leaf Scorch" and the two terms are still used more or less interchangeably in Maine. When first observed it was found in only a few orchards.[1] In succeeding years it was found in more orchards and a higher percentage of trees in these orchards became affected. A survey made in the fall of 1944 revealed the presence of varying degrees of magnesium deficiency symptoms in 47 out of 50 orchards. Thus it appears that leaf scorch or magnesium deficiency has become progressively more widespread and more severe in Maine apple orchards during the past ten years.

The symptoms of magnesium deficiency begin to show early in August. In early stages the older leaves of the current season's growth show a chlorosis at the tips and outside margins and in areas between the veins. Later, other leaves are affected and the chlorotic areas die and turn brown, giving the appearance of being scorched, hence the name "Leaf Scorch". During late August and early September the scorched leaves begin to drop. In severe cases trees may be almost completely defoliated by late September.

Trees affected with magnesium deficiency make comparatively small terminal growth and usually produce smaller fruit. In the McIntosh variety there appears to be a rather close correlation between the severity of magnesium deficiency and the amount of apple drop. It was even observed that on a given tree the branches that had the most leaf scorch dropped more apples than did the branches which showed little or no leaf scorch.

An experiment was started in one orchard in 1935 in an attempt to determine the cause and possible control of leaf scorch. Some of the treatments used included the addition of salts of phosphorus, potassium, magnesium, manganese, iron, and zinc. The trees which received potash showed somewhat more leaf scorch and those receiving magnesium showed somewhat less leaf scorch, but none of the treatments resulted in a definite control of leaf scorch during three years.

Since the addition of magnesium showed some reduction in the amount of leaf scorch, larger applications of magnesium were made in 1938. These consisted of ten pounds of Kieserite per tree and were applied to several trees which were severely affected. These treatments resulted in only a partial control in 1938, but a progressive improvement in these trees was observed in the following years.

These observations indicated that perhaps leaf scorch might be due to magnesium deficiency but that it took several years for apple trees to get sufficient magnesium from materials applied to the surface of the soil. An attempt was then made to see whether or not apple trees

[1]Leaf scorch was originally observed as a problem in Maine apple orchards by A. K. Gardner, Extension Crops Specialist at the University of Maine. Mr. Gardner also assisted in initiating and conducting some of the earlier experiments in the control of leaf scorch.

would absorb magnesium through their leaves. The first attempt consisted of spraying 27 trees with a 2 per cent solution of magnesium sulfate once in the month of July. This treatment reduced leaf scorch somewhat but did not result in anywhere near complete control.

The following year ten trees were sprayed three times during July with a solution of 40 pounds of Kieserite in 100 gallons of water. This treatment resulted in almost complete control of leaf scorch and greatly improved terminal growth and size of fruit.

In 1944, one, two, and three sprays of 20 pounds of Epsom salts per 100 gallons of water were compared on McIntosh trees in an orchard where leaf scorch readings had been taken for several years. The 27 trees which were not sprayed with magnesium showed 28 per cent more leaf scorch in 1944 than in the previous year while those that were sprayed showed reductions in leaf scorch of 11, 70, and 81 per cent respectively for those receiving 1, 2, and 3 sprays. In addition to showing less leaf scorch, the sprayed trees appeared to be making more terminal growth and to be improved in general vigor.

As soon as it was evident that appreciable control of leaf scorch could be obtained by spraying, the question arose as to whether magnesium could be added directly to the usual sprays used for insect and disease control. If this could be done without reducing the efficiency of the sprays, it would avoid the necessity of applying two or three extra sprays. In an attempt to answer this question, a small test was made in which both mild sulfur and lime-sulfur sprays with and without added magnesium were compared. Magnesium was added at the rate of 20 pounds of Epsom salts per 100 gallons of spray in each of four cover sprays and both leaves and fruit were examined[2] for apple scab control. These examinations indicated that the addition of Epsom salts to lime-sulfur sprays had no measurable effect on the control of scab on either leaves or fruit. The addition of Epsom salts to mild sulfur sprays resulted in no difference in scab on leaves but slightly more scab on fruits. In general, the experiment indicated that Epsom salts may be added to the regular sprays without seriously affecting their efficiency in the control of scab.

Additional experiments are in progress to study the effectiveness of Epsom salts and dolomitic limestone applied as soil treatments. Thus far the data secured indicate that various magnesium carriers added to the soil result in only a partial control of leaf scorch during the year of application. It may take three or more years before anywhere near complete control may be expected from soil treatments.

In view of the available data on this problem, it would appear that apple orchards located on soils low in magnesium should be limed with dolomitic limestone to prevent the development of leaf scorch. The apple orchards which already show magnesium deficiency, as manifested by the presence of leaf scorch, should be limed with dolomitic limestone and in addition should be treated with sprays containing 20 pounds of Epsom salts per 100 gallons of spray material, until the magnesium in the applied limestone becomes available to the trees.

[2]Leaves and fruits were examined for apple scab control by Dr. D. Folsom, Plant Pathologist, Maine Agricultural Experiment Station.

The Minor Element Content of Normal, Manganese-Deficient, and Manganese-Treated English Walnut Trees

By A. P. VANSELOW, *University of California Citrus Experiment Station, Riverside, Calif.*

PRACTICAL field methods for the correction of manganese-deficiency symptoms of English walnut trees have been described by Braucher and Southwick (1). At the time of this control work no determinations were made of the Mn content of the leaves of the trees in the test plot. Sometime later Mr. C. C. Delphey, Assistant County Agent, Santa Barbara County, supplied the author with leaf samples for the purpose of ascertaining the Mn status in the test plots. The spectrographic technique was used for making the analyses because this technique is capable, with only moderate additional effort, of yielding data for all the other minor elements that are detectable by this method. It is these data on the microelement content of the leaves of the English walnut tree that are presented in this article.

The description of these leaf samples from the Mn plots in Ventura County is given in Table I. These leaf samples were picked during the last part of June, 1941.

TABLE I—DESCRIPTION OF THE WALNUT LEAF SAMPLES PICKED FROM TREES IN LATE JUNE, 1941

Sample No.	Description
1	From unsprayed manganese-deficient trees having mottled and burned leaves. This sample was divided into three parts: slightly, moderately, and severely burned leaves.
2	From trees showing mottled and burned leaves. The trees had been previously sprayed in the early summer of both 1940 and 1941 with 5 pounds of manganese sulfate and 2½ pounds of soda ash per 100 gallons of water.
3	From trees sprayed in the early summer of 1940 with 5 pounds of manganese sulfate per 100 gallons of water. These trees received no subsequent treatment.
4a	From tree limb injected with 16 grams of the dry salt manganese sulfate in the early spring of 1939. This tree received no subsequent treatment.
4b	From a noninjected limb of the same tree as Sample 4a.
5	From apparently normal trees which had received no treatment of any kind.
6	From trees with trunk injections of 18 grams of manganese sulfate per tree in the early spring of 1940; the trees received no subsequent treatment.
7	This sample is from apparently normal trees located in Riverside These trees have received no fertilizer or spray treatments of any kind. This sample is included for purposes of comparison.

METHODS OF ANALYSIS

A detailed description of the spectrographic method of analysis used on these samples is being published elsewhere, but a brief description will be included here.

The leaf samples, when received, were washed by gentle rubbing by hand under a small stream of tap water. They were rinsed with

distilled water, wiped dry by means of clean towels, and dried at 55 degrees C in a well ventilated electrically heated drying oven. Sample 3 was divided into two parts when received, one part was washed as were the other samples, the other part was ashed and analyzed without being washed or wiped. This was done in order to obtain information on the extent of surface contamination. After being thoroughly dried the samples were crushed to suitable fineness by hand—no mechanical grinder or disintegrator was used in order to avoid the possibility of contamination with any metals. A suitable amount of each sample was ashed in an electric muffle furnace at a temperature not exceeding 500 degrees C. Ignition is done at this low temperature to avoid loss by volatility of any of the more volatile minor elements. Ignition at this temperature does not usually yield a white ash but rather it leaves the ash mainly in the form of the carbonates with small amounts of unburned carbon. The small amount of carbon left in the ash in no way interferes with the analysis by the spectrographic method.

Four parts of the sample ash were thoroughly mixed with one part of internal standard powder, which consists of highly purified sodium sulfate medicated with the four internal standard elements Tl, Ge, Pd, and Be. Four internal standard elements are used because it has been found that a single internal standard can not be depended upon when determining all the minor metallic components in one arcking. Craters of purified graphite were packed with 20 mg portions of the medicated ash and were arcked, using a direct current of 12 amperes. The spectrograms, after processing, were measured on a photoelectric densitometer and the results were computed on the graphic calculator described elsewhere (2).

Analytical Results

The results of the spectrochemical analyses are presented in Table II. The amounts of the minor components are expressed in parts per million in the dry matter. The arckings were made in triplicate, the results in the table are averages. The usual error is about 10 per cent, although a few of the values may be in error by as much as 20 per cent; the values, however, are sufficiently good for comparison purposes.

The table includes almost all the minor elements found in plant tissues analyzed in this laboratory. Two elements, cobalt and vanadium which are sometimes found in citrus material, were not positively detected in any of these walnut leaf samples; the limits of detectability for these two elements are: 0.2 parts per million for Co and .1 parts per million for V in the dry matter.

Discussion of Results

A. Manganese. Sample 1:—This sample from untreated trees suffering from manganese deficiency, shows approximately uniform content of Mn regardless of whether the leaves were green or badly burned.

TABLE II—MINOR COMPONENTS OF ENGLISH WALNUT LEAF SAMPLES. RESULTS ARE IN PARTS PER MILLION OF DRY MATTER

Sample	1			2	3		4a	4b	5	6	7
	Untreated Trees Mottled and Burned				Sprayed in 1940 Only		Same Tree				
Tree Treatment	Slightly	Moderately	Severely	Sprayed 1940, 1941	Washed	Unwashed	Limb Injected, 1939	Non-injected Limb	Apparently Normal Trees	Trees Injected 1940	Normal trees, Riverside
Ash, (Per Cent)	12.4	11.5	11.8	9.3	11.5	11.7	8.6	8.5	10.5	10.8	9.0
Ag	0.2	0.3	0.2	0.2	0.3	0.1	0.3	0.2	0.1	0.2	0.1
Al	22.0	27.0	25.0	80.0	35.0	80.0	70.0	65.0	10.0	20.0	45.0
B	125.0	100.0	95.0	75.0	75.0	90.0	70.0	85.0	105.0	110.0	180.0
Ba	8.0	7.0	10.0	17.0	12.0	12.0	6.0	6.0	6.0	8.0	18.0
Cr	ND*	ND	0.3	ND	ND	0.3	0.2	0.2	ND	0.2	0.2
Cu	11.0	9.0	10.0	11.0	14.0	8.0	4.3	4.2	9.5	8.0	9.0
Fe	32.0	35.0	40.0	60.0	60.0	130.0	85.0	100.0	50.0	40.0	45.0
Li	5.0	6.0	5.0	2.0	ND	ND	ND	ND	ND	2.0	ND
Mn	5.5	6.5	5.0	500.0	70.0	210.0	110.0	8.5	35.0	22.0	65.0
Mo	4.5	6.0	5.0	8.0	9.0	10.0	3.5	3.5	7.0	5.0	0.7
Ni	3.0	4.0	5.0	4.0	3.0	3.5	0.9	0.8	4.0	2.0	0.9
Pb	0.9	1.1	1.0	1.0	2.0	1.0	1.7	1.3	1.0	0.7	0.7
Sr	135.0	170.0	250.0	300.0	350.0	300.0	30.0	20.0	65.0	100.0	450.0
Ti	4.0	3.5	10.0	10.0	2.0	8.0	8.0	8.0	2.0	2.0	2.0
Zn	35.0	ND	ND	20.0	35.0	25.0	25.0	20.0	15.0	ND	18.0

*ND indicates "not detected." The lowest amounts of the various elements that can be detected vary considerably for the different elements and also depend on the absolute intensities of the individual arckings. The limits of detectability by the technique employed are: for Cr, 0.2 to 0.3; for Li, 2 to 3; and Zn, 15 to 20 parts per million in the dry matter having an ash content of about 10 per cent.

Sample 2:—This sample from trees which had been sprayed only a few months prior to sampling, is naturally very high in Mn. A large portion of this Mn may be spray residue on the surface of the leaves which was not removed by the washing technique here used.

Sample 3:—This sample from trees sprayed the year prior to sampling and which was analyzed in the unwashed as well as washed condition, shows an adequate amount of Mn in the leaves. The results for Al, Fe, and Si (not included in Table II) in the unwashed sample clearly indicate contamination of the leaves by soil dust. However, it is unlikely that the higher Mn content of the unwashed leaves can be due to soil dust on the leaves, if the soil contained enough Mn to contaminate the leaves to this extent there should be no Mn deficiency in that area. The higher Mn content of the unwashed leaves is in all probability due to drift from spraying operations on nearby trees in 1941. It seems quite unlikely that this much Mn could be left on the twigs and branches from the previous year's spraying and find its way onto the new leaves by the action of rain or fog. In view of this apparent contamination of the leaves by drift from nearby spraying operations and the possibility that the cleansing method was inadequate, it is not at all certain that the 70 parts per million of Mn found in the washed portion of Sample 3 actually represents a carry-over from the previous year's treatment.

Samples 4a and 4b:—These two samples from injected and non-

injected limbs of the same tree clearly demonstrate the efficiency of the dry salt injection method in providing the required Mn. They also show that there is no cross transfer of Mn from an injected limb to a nontreated limb. The Mn injected into the limbs or trunk of the walnut tree apparently moves readily from the site of the injection into the leaves.

Sample 5:—This sample of leaves from apparently normal trees does not contain as much Mn as does the leaf sample from the normal trees in Riverside; but apparently 35 parts per million of Mn in the leaves of the English walnut are sufficient.

Sample 6:—This leaf sample from a tree receiving 18 grams of the dry salt by the injection method into the main trunk does not show as high a Mn content as does Sample 4a, which however received 16 grams of the dry salt in the one limb from which the leaf sample was taken. Obviously, 18 grams of the dry salt per tree is not an adequate dose; this bears out the field observations of Braucher and Southwick.

While these data are too few for setting an arbitrary line of demarkation between sufficiency and deficiency of Mn in the English walnut tree, they are in line with the findings of other workers in regard to some other tree crops. Epstein and Lilleland (3) working with the Elberta peach found the Mn content of the leaves varied from 6 to 293 parts per million in the dry matter; they found that less than 17 parts per million constitutes a deficiency. Levitt and Nicholson (4) found in the case of Valencia oranges and Marsh grapefruit that deficiency symptoms were present when the Mn contents of the leaves were from 4 to 11 parts per million in the dry matter. At amounts of 25 to 30 parts per million, no deficiency symptoms were manifested.

Chapman, Liebig, and Parker (5) found with navel orange trees in outdoor sand cultures that 3 to 5 parts per million constituted a deficiency and 15 to 25 parts per million represented the normal content.

B. Other Minor Elements:—Silver was found to be present in all the samples at a concentration of a few tenths of a part per million. This is also the amount usually found in citrus leaf samples. However, in the case of citrus plants, amounts of silver as high as 1 part per million are sometimes encountered in samples from certain localities, and citrus leaf samples have also been analyzed in which the silver content was considerably under one-tenth of one part per million. We have also analyzed a few samples of walnut leaves from the Riverside area in which the silver content was exceedingly low.

The aluminum content of the samples was found to vary considerably. This may be the result of a variation in the degree of cleansing of the samples, especially in view of the results of the washed and unwashed portions of Sample 3. The underside of the walnut leaf is not smooth and it is conceivable that more drastic treatment is required to completely cleanse the leaves. The question as to how much of the aluminum found constitutes an integral part of the leaf tissue is unanswered. The aluminum contents of these walnut leaf samples

fall within the range of the Al content of citrus leaves, which are very smooth and easily wiped clean.

The boron contents of the Ventura County samples show only minor variation. All of them have a lower B content than does the one sample of normal leaves from the Riverside area. The boron content of all the samples is less than that reported by Kelley and Brown (6) for walnut leaves definitely known to suffer from excessive amounts of boron. The boron contents of these walnut leaf samples are comparable with the amounts usually found in normal citrus leaf samples.

The amounts of barium found were somewhat variable but were much lower than the amounts usually found in normal citrus leaf samples.

Chromium was detected in the majority of the samples but the amount found is only slightly in excess of the minimum concentration that can be positively detected. This does not necessarily mean that Cr is not present in some samples, it merely indicates that the amount present is less than the concentration detectable by the method used. In the case of normal citrus leaves the Cr situation is quite similar with a somewhat lower proportion of the samples showing Cr positively.

Both copper and iron showed considerable variation in the amounts found and both these elements show about the same range of concentration as occurs in leaf samples from unsprayed normal citrus trees.

The element lithium was positively detected in 3 of the 7 samples; in 2 samples, (2 and 6), the amount found was just sufficient for positive detection. The remaining samples may or may not contain Li; if present, the amount is less than 2 to 3 parts per million. Of several hundred citrus leaf samples examined only one showed Li positively, and that one sample was not a normal leaf sample.

All the Ventura County samples were substantially higher in molybdenum content than was the one sample from Riverside; this one sample is quite typical of walnut leaf samples from the Riverside area. Normal citrus leaf samples frequently do not have enough Mo for detection, the minimum amount detectable being approximately 0.4 parts per million. The normal citrus leaf seldom has a Mo content exceeding one part per million.

The nickel content of most of the Ventura County samples was higher than that of the single sample from Riverside. Citrus leaf samples normally have a much lower nickel content than do these walnut leaf samples. In fact, they frequently have less than the minimum detectable by our method, namely, 0.2 to 0.3 parts per million.

The amounts of lead found in the samples are low and quite uniform and of about the same magnitude as that of normal citrus leaves.

The amount of strontium found was extremely variable, but the amounts and range of variation are about that found in citrus leaf samples.

No significance should be attached to the titanium values, due to the fact that this element is one of the few impurities present in the

graphite craters used in the arcking of the samples and it is extremely difficult to remove completely.

The zinc content shows some variation among the samples. In those few cases in which zinc was not positively detected this may have been due to lower general sensitivity occasioned by uncontrolled variations in arcking conditions.

In general, it may be said that the presence of or the correction of manganese deficiency appears not to have affected the content of the other minor elements.

Summary

Spectrographic analyses have been made of samples of walnut leaves from untreated and treated manganese-deficient trees, and from normal trees in two areas.

The results for 15 of the minor elements are presented. They show that a manganese deficiency can be corrected by spraying the tree during early summer or by the injection of the dry salt into holes in the trunk or limbs of the walnut tree.

A deficiency of manganese does not seem to cause any material disturbance in the amounts of the other minor elements found in the leaf samples.

Considerable differences were found in a few of the minor elements between normal leaf samples from the two areas. This is undoubtedly the result of differences in the content of those minor elements in the soils of the two areas.

In general, the minor element content of the walnut leaf does not differ greatly from that of the normal citrus leaf; barium is somewhat lower in the walnut leaf, and Mo, and Ni are somewhat higher in the walnut leaf.

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Increasing Available Potassium to Greater Depths in an Orchard Soil by Adding Potash Fertilizer on a Mulch

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Several reports (1, 2, 3) have been made relative to the fixation of potassium in such form as to be unavailable to plants. It is believed that this phenomenon is due to the combined effects of two actions. One is the effect of free alumina in forming muscovite or some closely related mineral which contains potassium in an unavailable form, the other is the result of alternate wetting and drying of the exchange material containing potassium thus causing the latter to be held in an unavailable form.

Investigations carried out at the Agricultural Experiment Station at Wooster, Ohio, indicate that the difficulty of fixation can be obviated in orchards by the use of a heavy mulch of straw, hay or similar plant material. It was found that the potassium which leached from unweathered mulch material remained more mobile and penetrated to greater soil depths in an available form than did potassium supplied as fertilizer on top of a sod (4). This is believed due to the conditions which are obtained under a mulch, that is, a more constant moisture content of the soil under the mulch, an insulation effect allowing for a more constant soil temperature, an increased organic matter supply which provides exchange material which does not trap potassium, and increased porosity which is brought about by the mechanical or stirring action of earthworms and other animal life under the mulch.

The above situation relates to the potassium which leaches from plant material while the study here reported was made to determine the behavior of potassium supplied as fertilizer on top of a mulch.

Treatments

Treatments consisted of establishing mulches of unweathered wheat straw and unweathered but mouldy soy bean hay under six Stayman Winesap apple trees of equal vigor, for each of the two types of mulch. Four trees, two under each type of mulch, then received 10 pounds of 60 per cent KCl each year for a period of 3 years, four trees with identical mulch treatments received 5 pounds of 60 per cent KCl for the same length of time and four trees received the mulch only. Trees in sod receiving no potash fertilizer or mulch were used as controls to note any seasonal fluctuations in available potassium. No sod trees with added potash fertilizer were included in this experiment, since it had previously been found that potassium added as fertilizer was relatively slow in penetrating the soil.

All mulches consisted of 200 pounds each year for the 3-year period of either the wheat straw or soy bean hay brought into the orchard and spread beneath the drip of the branches.

Sampling Technique and Analytical Procedure

Samples were taken with a soil tube to a depth of 18 inches. Ten samples were taken beneath each tree, each sample cut into three 4-inch levels and one 6-inch level, the lowest sample. These divisions from the ten samples were then composited thus from under each tree. After the samples were air-dried, they were crushed with a hardwood rolling pin, screened through a 2 mm sieve, thoroughly mixed and stored in air-tight jars. Samples from all treatments were taken during May and September for 3 consecutive years. The first set of samples were taken just prior to the start of the various treatments with mulch and fertilizer.

The exchangeable potassium content of the soil was obtained by leaching a 10 gram sample wtih 250 ml of neutral normal ammonium acetate, evaporating the leachate to dryness, destroying the organic matter and excess ammonium salts, and determining potassium by the method outlined by Wander (5).

Results

The parts per million of exchange potassium in the soil at different depths under the various treatments during a 3-year period are presented graphically. (Figs. 1 & 2). With either the straw or soy bean

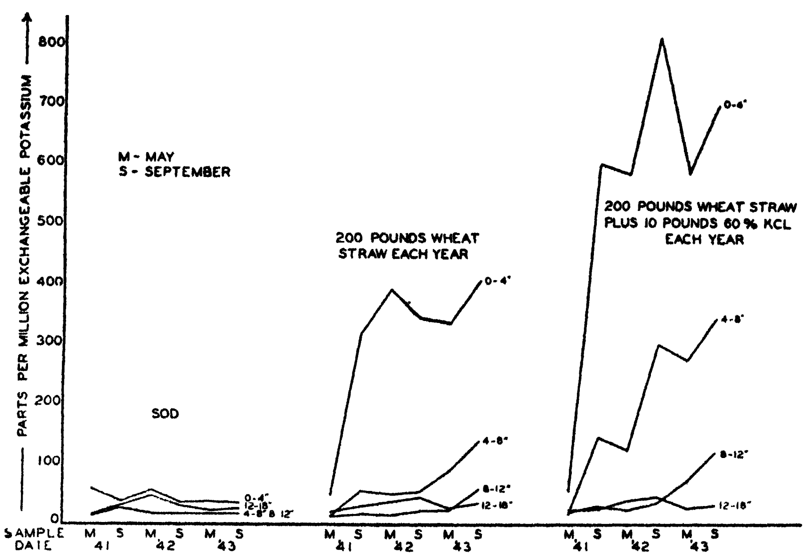

Fig. 1. The amounts of exchangeable potassium at different soil depths during a 3-year period under sod, straw, mulch, and straw mulch with additional potassium supplied as fertilizer.

hay used as mulch and without the addition of a potash fertilizer, a considerable increase in exchange potassium is found in the first 4 inches of soil beneath the mulch. This occurred when the mulch had been in place only 4 months. A smaller, but appreciable, increase of

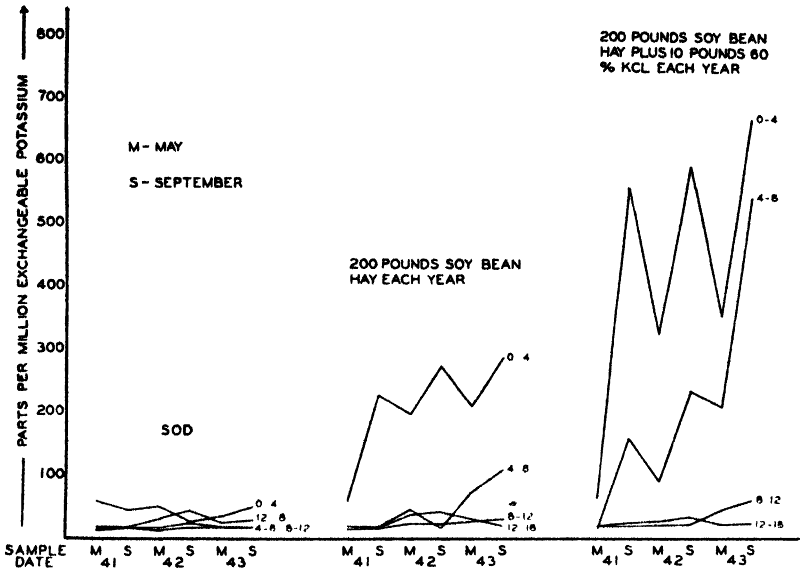

FIG. 2. The amounts of exchangeable potassium at different soil depths during a 3-year period under sod, soy bean hay mulch, and soy bean hay mulch with additional potassium supplied as fertilizer.

potassium was noted in the 4- to 8-inch level after the 3-year period. The increase in exchange potassium in the 8- to 12-inch level was small but had risen above the 12 to 18-inch level. Where no mulch is used the 8 to 12-inch level is consistently lower than the 12 to 18-inch depth.

Where 10 pounds of potash fertilizer were added to the mulch, the response was immediate and quite pronounced. Besides the 0–4-inch depth, the 4 to 8-inch depth was definitely increased after the 3-year period. No effect was noted at the 12 to 18-inch depth.

The results for the treatment consisting of mulch plus 5 pounds of 60 per cent KCl were not graphed. These results lay just between the mulch alone and mulch plus 10 pounds of 60 per cent KCl.

Conclusions

It is apparent that the conditions which exist under a heavy mulch on a Wooster silt loam soil are favorable in preventing potassium from becoming fixed in the top portion of soil. This allows exchangeable potassium to penetrate to sufficient depth to include most of the roots of fruit trees on this soil type.

If it is necessary to supply potassium in larger amounts and more quickly than would be supplied by mulch material alone, it may be applied as muriate of potash or some other potash salt, directly to mulch. Such a procedure allows the potassium to remain mobile instead of being fixed in unavailable form at or near the soil surface.

Summary

The phenomenon of potassium fixation at or near the soil surface when applied as a potash fertilizer can be practically eliminated in orchards where a mulch is used. Data are presented which show that when 10 pounds of potash as 60 per cent KCl are added to a heavy mulch the soil to a depth of 1 foot will be greatly increased in exchange potassium within a period of 3 years. Within 4 months of the start of such treatment, soil to the depth of 8 inches was increased in available potassium. In no other known way, except by mechanical placement, can potassium be increased to such a degree.

Where a lack of potassium may be a limiting factor in orchard production, this element may be quickly supplied in available form when used in conjunction with a mulch. The conditions under a mulch allow potassium to permeate thoroughly the zone of greatest root concentration.

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Increased Fruit Set of Anjou Pear with Heavy Application of Nitrogen[1]

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An increased fruit set of Anjou pear was obtained on adobe soil at the Medford, Oregon, Experiment Station in 1944, following the soil application of extremely large amounts of nitrogen. Although additional investigations will be necessary to understand the significance of these results, they justify a brief discussion at this time.

The Anjou pear generally produces an abundance of blossoms, but frequently sets only a light-to-medium crop of fruit, particularly when grown on adobe soil. Studies of factors affecting fruit set of Anjou on adobe soil have been made at the Medford Experiment Station (1, 2). Several years ago it was found that soil applications of 2 to 3 pounds of nitrogen per tree resulted in somewhat greater set of fruit in some seasons than was the case where no nitrogen had been applied for 2 years or more. Since the loss of nitrogen from this soil by leaching would be expected to be negligible, annual applications of 1½ to 2 pounds of nitrogen per tree were expected to be satisfactory to maintain adequate soil nitrogen for these trees.

In the fall of 1943 a new experiment upon infiltration of irrigation water was started, using a block of 27-year-old Anjou trees that had been receiving 2 pounds of nitrogen per tree annually for 10 years. Each plot consisted of three trees, and each of the four treatments listed in Table I was replicated five times. In October, after the 1943 crop was off, the trees received: in treatment 1, 1½ pounds of actual nitrogen per tree in the form of ammonium sulfate; in treatment 2, 10 pounds of actual nitrogen per tree in the form of alfalfa hay; in treatment 3, 10 pounds of nitrogen per tree in the form of straw and ammonium sulfate; and in treatment 4, 10 pounds of nitrogen per tree in the form of ammonium sulfate. The pertinent data are presented in Table I.

All the trees produced a fairly good crop in 1942, but a very light crop in 1943, due to low temperatures in March. In 1944, the first season after the treatments, the trees that had received 10 pounds of nitrogen per tree (50 pounds of ammonium sulfate or its equivalent) yielded more than the trees that had received only 1½ pounds of nitrogen per tree. These greater yields with 10-pound applications of nitrogen apparently were largely the result of increased percentage of blossoms setting fruit.

Anjou pears growing on heavy soil in the Medford district normally develop only a few seeds, and many seedless fruits are produced.

[1]This is a report of a cooperative project between the U. S. Department of Agriculture and the Oregon Agricultural Experiment Station. This report is published as Technical Paper No. 460 of the Oregon Agricultural Experiment Station with the approval of the director of the Oregon Agricultural Experiment Station and the chief of the U. S. Bureau of Plant Industry, Soils, and Agricultural Engineering.

TABLE I—EFFECT OF THE APPLICATION OF TEN POUNDS OF ACTUAL NITROGEN PER TREE UPON THE SET OF FRUIT OF ANJOU PEAR

Treatment No.	Fertilizer* Application Per Tree	Amount of Nitrogen (Pounds)	Yield** (Field Lugs) 1942	1943	1944	Percentage Sets† 1944	Seeds Per Fruit 1944
1	Ammonium Sulfate 7.2 pounds	1.5	12.7±.57	3.0±.47	9.8±.41	1.3	0.85
2	Alfalfa hay 400 pounds (surface mulch)	10	12.2±.49	3.6±.36	13.0±.41	1.9	0.30
3	Straw 400 pounds (surface mulch) plus ammonium sulfate 40 pounds	10	12.7±.52	3.3±.26	14.4±.63	1.8	—
4	Ammonium Sulfate 50 pounds	10	11.3±.39	2.5±.22	12.5±.54	2.1	0.35

*Fertilizer and mulch spread over entire surface of the ground, after the 1943 crop was harvested.
**Average of three trees for each plot.
†Average of one tree for each plot.

The lower average seed content per fruit in treatments 2 and 4 than in treatment 1 indicates that the 10-pound nitrogen application had stimulated the set of more seedless fruit in the spring of 1944 than had occurred with the 1½-pound nitrogen application. Cool and rainy weather during the blossoming season of 1944 was unfavorable for pollination and the observed differences in set might not be obtained in a year when pollination conditions were more favorable.

Samples of fruit from treatments 1 and 4 were placed in cold storage on September 16 and 20, 1944, respectively. On September 20 the fruit from treatment 4 gave the same pressure test reading as fruit from treatment 1 on September 16. A sample of fruit was removed from each storage lot on January 6, 1945, and was examined and ripened. The difference in firmness between treatments 1 and 4 had largely disappeared, indicating that the fruit from treatment 4 had softened somewhat more rapidly during the first three months of storage. All samples had excellent quality when ripe.

A second sample of fruit was removed from storage on February 3, 1945, and ripened. At this time the fruit from treatment 4 reached prime eating condition 24 hours sooner than fruit from treatment 1. No other differences were noted in these samples. All of the fruit developed excellent quality. Other samples will be removed at later dates.

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Pressure Injection of Iron Sulfate into Citrus Trees

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IRON deficiency, chlorosis, or lime-induced chlorosis occurs rather commonly in the citrus growing sections of California. It is quite serious in some localized areas, particularly where the lime content of the soil is high. In general, the soils and irrigation waters are quite high in calcium in Ventura County, and chlorosis is a rather common difficulty.

FIG. 1. Leaf symptoms of iron deficiency. Photos by L. J. Klotz.

EQUIPMENT

In an effort to find possible improved methods of correcting iron deficiency, the following liquid pressure injection equipment was developed. This equipment consists of three 4-gallon iron containers built airtight (State of California hot water specifications 200 pounds pressure), with opening in top to put liquid in, a valve stem from an old inner tube in the top for applying air pressure, and an outlet pipe extending from bottom of container through the top with T couplings and nipples so that four hoses and valves can be connected to the out-

[1]Appreciation for the many helpful suggestions, guidance, and encouragement in this work is extended to Dr. J. P. Bennett, J. C. Johnston, Dr. David Appleman, Dr. S. H. Cameron, Dr. W. H. Chandler, and J. P. Fairbank. The author thanks John Lawton, W. P. Daily, and Paul Daily for furnishing citrus trees with which to work and making facilities available for carrying on this work.

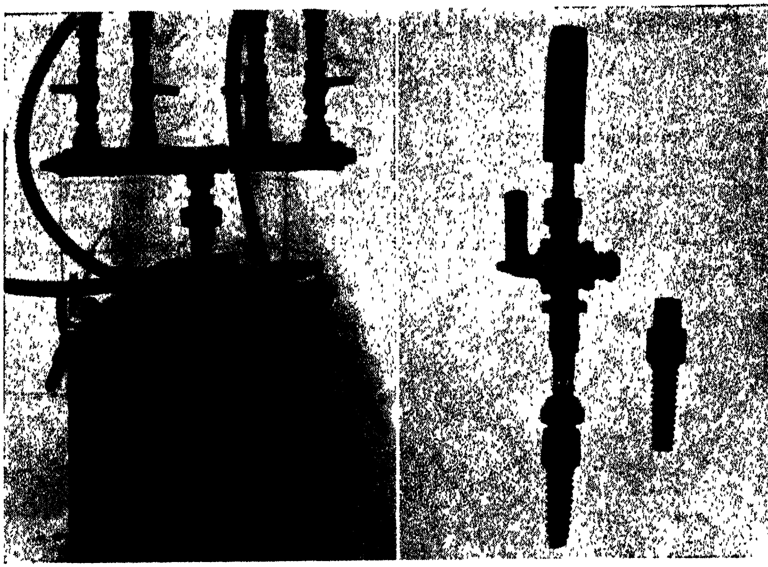

FIG. 2. Injection equipment. (Left) Container with hoses showing valve at base of hose. (Right) Nipples and valve showing valve mounted at end of hose.

let pipe. Attached to the end of the hose by coupling is a brass nipple which can be screwed into holes drilled into the trees.

The picture shows the valves for shutting off the individual hoses at the top of the container. It is much more convenient when this valve is at the end of the hose. The metal containers received a coat of protective paint to prevent corrosion. It was impossible to secure hose couplings that would not rust in the threads. The nipple that screws into the hole bored in the tree has hose thread on one end to fasten hose coupling on. The other end has lag screw threads, with a slight taper for easier starting and to make them fit tight next to the bark when they are screwed in, helping to keep down bark injury.[2] Air pressure was secured from a small portable air compressor, operated by a 1½-horse power gasoline engine.

PROCEDURE

Only trees severely affected by chlorosis were selected for injection treatment, and most of the work was done in cool weather as injury seemed to be less when done then. Reasons for variation in injury are not clear.

Liquid pressure injections were given to approximately sixty 15-year-old Valencia orange trees in the Fillmore district, and about two hundred 30-year-old lemon trees in the Camarillo district of Ventura County.

[2]Nipple developed by Dr. J. P. Bennett.

The material to be injected was dissolved in 1 gallon of water and placed in the 4-gallon container, leaving 3 gallons of air space after closing the container. Air pressure was applied through the valve stem to between 80 and 100 pounds per square inch. With the slow leaks that are prevalent under these conditions, the pressure was usually reduced to about 50 to 60 pounds per square inch by the time the gallon of liquid was taken up by the tree.

After the liquid is placed in the container and air pressure applied, four 3/8-inch holes, 4 inches deep, are bored in the trunk of the tree on chords of the circle formed by the circumference of the tree trunk. The holes are placed as near the circumference as possible, distributing them as evenly as possible around the tree. The holes are bored at about a 10-degree angle so they can be filled with solution and the air forced out. After the holes are filled with liquid and the nipples screwed into the trees, the hoses are connected, removing as much of the air as possible as they are connected, and the pressure turned on in each individual hose.

It requires from 15 minutes to 3 hours for a gallon of liquid to pass into the tree. The shorter periods of time occurred in injecting old lemon trees on days when a strong coastal wind was blowing, while the longer periods of time occurred with 15-year-old Valencia orange trees on calm days.

Concentrations of from 30 grams to 200 grams of ferrous sulfate per tree were used, alone or in combination with manganous sulfate, zinc sulfate, or copper sulfate, on Valencia oranges and lemon trees.

Results

A very even distribution of iron to all the foliage of a citrus tree by liquid pressure injection was secured, using from 30 to 200 grams of ferrous sulfate per tree, with correction of chlorosis resulting from all treatments.

Six trees receiving 30 to 35 grams of ferrous sulfate remained free from chlorosis approximately two years. About fifty trees receiving 50 grams of ferrous sulfate remained free from chlorosis for 2 to 3 years. Of eleven Valencia orange trees treated with 70 to 80 grams of ferrous sulfate per tree, two were free from chlorosis 2 years; one was free from chlorosis 3 years; and eight were free from chlorosis for 4 years. Of forty-two Valencia orange trees receiving 100 grams of ferrous sulfate, five were free from chlorosis 3 years; seventeen were free from chlorosis for 3 to 4 years; and twenty were free from chlorosis 4 years.

Over two hundred old lemon trees were treated with quantities of ferrous sulfate, ranging from 75 to 200 grams. All of these trees remained free from chlorosis for 3 years.

After chlorosis starts to re-appear in the treated trees, it is a year or two before the chlorosis becomes as bad as it is on untreated trees used as check trees.

To determine whether an abundant supply of iron was getting to

the leaves and bark, samples of solution were taken from limbs while the pressure was on, and samples of leaves were secured for analysis.[3]

The first tree used in this work is the tree referred to under treatment No. 27, which received an injection of 50 grams of ferrous sulfate in 1½ gallons of water on April 14, 1941. Just prior to starting the injection, a sample of leaves and bark was taken for analysis, and one large limb was sawed off so that a sample of liquid could be collected while the injection was going on. The following data were secured.

Liquid Samples — April 14, 1941

No. 1—Ferrous sulfate solution before injection ... 2670 ppm iron
No. 2—Solution from limb while injection going on .. 1780 ppm iron

Iron Concentration, Leaves and Bark, Tree No. 27
Before and After Injection

Leaves before injection 41.5 iron ppm dry weight of leaves
Leaves after injection 865.0 iron ppm dry weight of leaves
Bark before injection 15.7 iron ppm dry weight of bark
Bark after injection 100.5 iron ppm dry weight of bark

These figures indicate considerable accumulation of iron in the leaves and bark of the tree.

Also, at the time of collection of leaves after injection of the tree represented by treatment No. 27, a sample of leaves from a tree represented by treatment No. 28 which had received 200 grams of ferrous sulfate per gallon of water was collected on April 14, 1941, for iron analysis. These leaves were badly burned and dropped from the tree. This sample showed 2712 parts per million iron per dry weight of leaves.

On April 14, 1941, a sample of leaves was taken from tree represented by treatment No. 29, prior to injection, and again on August 29, 1941,—over 4 months after treatment. Tree No. 29 received 100 grams of technical ferrous sulfate and 10 grams of manganous sulfate (commercial) per tree.

Leaves before injection 57.0 ppm iron dry weight of leaves
Leaves 4 months after injection 499.0 ppm iron dry weight of leaves

Also, leaf samples were taken from various parts of the trees represented by treatment No. 30, on April 14, and August 29, 1941. The following is a summary of these analyses:

Before injection, south side 36 ppm iron dry weight of leaves
After injection, south side 807 ppm iron dry weight of leaves
Before injection, center 88 ppm iron dry weight of leaves
After injection, center 410 ppm iron dry weight of leaves
Before injection, west side 51 ppm iron dry weight of leaves
After injection, west side 1270* ppm iron dry weight of leaves

*Original tagged twig lost all of its leaves, sample taken from adjoining twig.

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[3]Analytical work done by Dr. David Appleman, Assistant Professor of Plant Nutrition, University of California at Los Angeles.

On February 5, 1942, the tree represented by treatment No. 46 was injected with a solution carrying 50 grams of ferrous sulfate (commercial) per gallon of water. Limb No. 1 was sawed off and samples of liquid coming from this limb were collected at various intervals, following the start of the injection. A notch was cut in a smaller limb, limb No. 2, and one sample collected from this limb. The following analyses were secured:

Original solution, before injection, of 50 grams ferrous sulfate per gallon of water—3200 parts per million iron.

Limb No. 1—solution from 1–5 minutes after start of injection—1450 ppm iron

Limb No. 1—solution from 5–8 minutes after start of injection—1900 ppm iron

Limb No. 1—solution from 15–17 minutes after start of injection—2100 ppm iron

Limb No. 1—solution from 25–30 minutes after start of injection—2100 ppm iron

Limb No. 2—solution from 5–20 minutes after start of injection—800 ppm iron

Pressure was cut off at 12:00 noon on February 5. The equipment remained in place and was started again on February 6 at 8 a. m.

Limb No. 1—solution 1–5 minutes after starting on February 6—1240 ppm iron

Limb No. 1—solution about 35 minutes after starting on February 6—1800 ppm iron

Considerable injury resulted from the use of 200 grams of ferrous sulfate per tree and this amount is stronger than needs to be used for citrus trees. In a number of cases, the 70–100 gram per tree injection caused injury which killed small twigs. It is not clear why some of the trees receiving these concentrations of solution are injured and other trees are not injured sufficiently to kill twigs. Injury to the chlorotic foliage and a few twigs results in a rapid recovery and the production of normal foliage, with the setting of normal crops the year after injection.

CONCLUSION

Liquid pressure injections of ferrous sulfate at strengths of 50 to 100 grams per tree will correct chlorosis for two to four years, with an even distribution of iron throughout the tree. This method occasionally causes severe injury to the small twigs of a tree. The reason for this occasional injury is not clear from this work.

Effect of Nitrogen Level on Freezing Injury to Growing Blossom Buds of the McIntosh Apple

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An experiment in which trees have been carried at different nitrogen levels since 1942 afforded opportunity to study the influence of the nitrogen level on the susceptibility of blossom buds to freezing injury during spring growth (1).

The work was done on McIntosh trees, planted in 1925, in a sod orchard at Peru in the Champlain Valley of New York. The principal injury evidently occurred as a result of minimum temperatures of about 20 degrees F on the nights of April 15 and 16, 1945, when most blossom buds were in a tight-cluster stage, and of about 21 degrees F the night of April 23, when buds varied from a tight-to an open-cluster stage. The readings were taken near but not in the experimental plot.

The comparisons were between paired, low- and high-nitrogen trees. Until 1942, all trees were of medium vigor as a result of uniform, moderate annual applications of nitrogen. In 1942, 1943, and 1944, nitrogen was omitted from the low nitrogen trees, while an application of 2½ pounds per tree was given on April 19, 1945. In the spring of each of these 4 years, the high nitrogen trees received ten pounds of ammonium sulfate in a ring beneath the tips of the branches. Both sets of trees received 4 pounds of 60 per cent muriate of potash in the spring of 1944 and 1945.

From 1942 through 1944, the low-nitrogen trees gradually decreased in yield, growth, nitrogen content of leaves, and depth of foliage color, relative to the high-nitrogen trees. In July of 1944, leaf samples from the high-nitrogen trees averaged 2.37 per cent nitrogen in their dry weight, whereas leaf samples from the low nitrogen trees averaged 1.52 per cent nitrogen. The 1944 average yield from the high nitrogen trees was 16.8 bushels and it was only 6.5 bushels from the low nitrogen trees. The high-N trees had much darker green foliage, and made more vegetative growth than did the low-N trees, although the shoot growth was only moderate at best. It seems doubtful that the light ammonium sulfate application in 1945 could have had much effect by the time of the cold nights that caused the bud injury.

For comparison of the extent of injury, 20 spurs from each tree were selected at random, at a height of about 6 feet. No attention was paid to the advancement of the buds in taking this sample. Each bud was sectioned free-hand, in the laboratory, and those with macroscopic masses of brown tissue in the vicinity of the ovaries were recorded as dead. Rather widespread browning of petals and of the inner aspect of the sepals was ignored, as observation in previous years had indicated that such browning did not always preclude setting of the fruits. Killing of the pistils was fairly well correlated with occurrence of the browning in the vicinity of the ovaries, but seemed a

less dependable criterion because aging, rain and other factors had made the condition of certain pistils in open blossoms less clear-cut.

Observation showed that the buds were more advanced on the high-nitrogen trees. Therefore, another sample of blossoming spurs was taken from each tree. In this latter instance the least advanced buds were chosen; otherwise, the sample was random. While the buds from the high-nitrogen trees may have been slightly more advanced than those from the low-nitrogen trees, any possible difference was very small.

Toward the end of bloom a visual estimate of the percentage of petals that had fallen was taken as an index to the relative advancement of the blossoms on the individual trees.

Results and Discussion

The data are summarized in Table I. From Table I it is apparent that the killing of buds was more extensive on the high-nitrogen trees, but that this difference was not evident when buds were selected at a retarded and similar stage of advancement. Since the high-nitrogen trees are shown to have buds at a more advanced stage, it appears that their greater tenderness was due, at least in part, to their advancement. A survey of commercial McIntosh orchards in the area corroborated the results obtained from these experimental trees.

TABLE I—Influence of Nitrogen Level on Killing of Blossom Buds of McIntosh Apple in 1945

Pair of Trees (Number)	Percentage of Live Buds in Random Samples		Percentage of Live Buds in Samples at a Similar Stage of Maturity		Advancement of Buds as Indicated by Percentage of Petals Fallen, by May 9, 1945	
	Low N	High N	Low N	High N	Low N	High N
2	25	13	24	17	80	85
3	34	21	25	22	25	75
4	34	21	37	20	50	75
5	29	31	29	27	50	75
6	48	30	30	38	45	75
7	33	27	38	39	55	80
8	33	20	27	31	80	70
9	41	27	43	49	50	80
10	26	15	37	30	60	70
12	34	31	51	43	70	85
13	27	34	34	30	40	85
14	42	19	37	30	80	80
15	37	31	34	37	35	70
16	36	30	32	31	35	50
17	43	21	39	39	70	75
18	39	22	42	32	50	70
Mean	35.1	23.9	34.9	32.2	54.7	75.0
L.D. 5 per cent level	3.8		—		8.6	
L.D. 1 per cent level	5.2		—		11.9	

There is some question as to the reasons for the greater advancement of the flower clusters from the high-nitrogen trees. The buds of those trees may have opened earlier, or may have developed more rapidly following opening. Support for the latter possibility is found

in the work with peach trees in North Carolina by Williams (4) who found that nitrogen did not influence the time of visible bud activity in the spring, but that the rate of development was increased by relatively high nitrogen.

The fact that the bloom of these high nitrogen trees was more advanced than that of the low nitrogen trees at the time of injury is not consistent with other evidence to indicate that vigorous trees tend to blossom somewhat later than weak ones (2, 3). This is not surprising in view of the complexity of physiological relationships involving "vigor".

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Observed Responses of Apple and Pear Trees to Some Irrigation Waters of North Central Washington

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The question of the productive life expectancy of western fruit trees under irrigation is often raised. Of greatest concern, perhaps, is the possible drain of soil nutrient resources which aridity has conserved for centuries. After many years of intensive fruit cropping under rather heavy irrigation, the loss of soil nutrients apparently has not been found to be a serious limitation. Irrigation waters contain soluble plant nutrients and probably assist in the restoration of certain salts removed by drainage. The kind and amount of salts, however, vary with different waters and the effects of some waters may exert a pronounced influence on soil structure, nutrient availability, acidity, and base exchange relationships. This report deals with observed responses of apple and pear trees irrigated over a period of years with waters containing relatively low amounts of Na and Cl ions in relation to the amount of Ca, Mg. SO_4, and HCO_3 ions.

The Columbia River and its tributaries provide irrigation water to all but a relatively small percentage of the orchards in the Wenatchee and Okanogan fruit districts of Washington. These waters are characterized by rather low concentrations of dissolved salts, the amounts varying roughly between 40 and 200 p.p.m. of total solids. The quality of these waters is indicated by the fact that many apple and pear trees 40 to 45 years of age are still growing vigorously and cropping heavily, and there is no suggestion at the present time of tree decline attributable to deleterious effects of these waters.

In recent years, attention has been directed to certain orchard locations where trees have shown marked lack of vitality irrespective of good cultural practices and careful management. In practically all instances these orchard soils gave strong positive tests for carbonate, although the original plantings were not made on calcareous soil.

Chlorosis of fruit trees has frequently been found in orchards receiving sub-surface irrigation from higher levels. Analyses of these waters showed varying concentrations of calcium and magnesium bicarbonate, the totals ranging from 175 to 400 p.p.m. of total bicarbonate. Appreciable quantities of carbonate were also found in the soil. Apparently these ground waters contained salts principally derived from percolation through limestone strata located at higher altitudes. Geological surveys of the area have disclosed the existence of such lime formations.

In addition to orchards showing chlorosis and tree decline in seepage areas, chlorosis and loss of vigor have also been observed in certain orchards where neither seepage nor parent lime deposits could be associated with the trouble, although carbonate was present in the soil. The source of irrigation water in these orchards was either wells, springs, or small creeks, and upon analysis the water showed appre-

TABLE I—ANALYSES OF SOME IRRIGATION WATERS USED IN THE FRUIT GROWING REGIONS OF CHELAN, DOUGLAS, AND OKANOGAN COUNTIES OF WASHINGTON

Water Source	Date Sampled	Conductance K × 10^5 at 25 Degrees C	Ion Concentrations Expressed as Parts per Million and Milliequivalents per Liter														pH
			Ca		Mg		Na		HCO_3		SO_4		Cl		NO_3		
			PPM	ME	PPM	ME	PPM	ME	PPM	ME	PPM	ME	PPM	ME	PPM	ME	
Group A																	
Wenatchee River	7/11/44	5.7	9.8	0.49	1.6	0.13	4.5	0.20	32	0.52	3.0	0.06	1.0	0.03	—	—	7.4
Similkameen River	6/16/44	7.7	17.2	0.86	1.1	0.09	2.2	0.09	45	0.74	6.0	0.12	0	0	0	0	7.8
Columbia River	7/11/44	14.4	26.8	1.34	5.0	0.41	3.3	0.14	76	1.25	11.0	0.23	0	0	0	0	8.2
Entiat River	8/11/44	12.1	22.0	1.10	4.4	0.36	3.3	0.14	70†	1.15	8.0	0.17	1.0	0.03	0.40	0.01	8.4
Okanogan River (at Riverside)	6/11/44	*17.8	21.0	1.05	1.3	0.11	3.3	0.14	60	0.98	22.0	0.46	0	0	—	—	7.8
Salmon Creek	6/16/44	22.8	50.0	2.50	1.8	0.15	1.2	0.05	91	1.49	44.0	0.92	0	0	1.1	0.02	8.1
Lake Chelan	5/14/41	5.0	—	—	—	—	—	—	25	0.41	—	—	—	—	—	—	6.5
Group B																	
‡Cn, Well	8/18/44	*64.4	67.4	3.37	23.8	1.95	30.1	1.31	307	5.03	85.0	1.77	2.5	0.07	4.7	0.08	7.8
Se, Creek	6/16/44	*40.0	48.6	2.43	27.2	2.23	16.2	0.70	259	4.25	111.0	2.31	0.5	0.01	—	—	8.3
Jn, Creek	10/7/43	58.0	103.0	5.15	44.0	3.61	—	—	266	4.36	81.0	1.69	—	—	—	—	7.7
Ca, Well	8/31/44	*59.9	84.8	4.24	22.5	1.84	12.7	0.55	260	4.26	145.0	3.02	3.0	0.08	4.7	0.08	7.4
Ck, Well	8/31/44	*51.2	79.0	3.95	15.1	1.24	13.9	0.60	210	3.44	128.0	2.67	1.0	0.03	7.4	0.12	7.7
Ln, Spring	6/9/43	57.0	—	—	—	—	—	—	280	4.59	—	—	—	—	—	—	8.2
Os, Spring	6/30/43	67.1	—	—	—	—	—	—	360	5.90	—	—	—	—	—	—	8.2
Mc, Well	7/23/40	56.0	—	—	—	—	—	—	267	4.38	—	—	—	—	—	—	7.9

†1.0 ppm carbonates.
*Due to some precipitation of carbonates in the water, values given for conductance, calcium, and magnesium are slightly low.
‡The abbreviations designate particular orchards.

ciable quantities of bicarbonate. The origin of these waters was, in some cases at least, identical with the source of ground or seepage water and probably the only distinguishing characteristic of the two, from the standpoint of soil effect, was the length of time the water had been wetting the soil. There is no accurate way of knowing the number of years seepage has been altering the soil character, but a record may be had of the period during which certain waters have been transported to an orchard site for surface application.

It is generally recognized that much bicarbonate in irrigation waters tends to increase soil alkalinity. During the drying of soil, CO_2 is lost from the bicarbonate ion and calcium and magnesium carbonate are precipitated. The concentrations of bicarbonate ions in the wells, springs, and small streams of the present survey were from 200 to 360 p.p.m. Salt content of any water will vary somewhat with the time of year at which it is sampled, but the magnitude of these variations during the irrigating season has not been significant from the standpoint of purpose in these studies. Some analyses of waters used for irrigation are shown in Table I.

Water sources under Group A supply the requirements of highly developed irrigation systems, and represent the supply for a large percentage of orchard acreage in the Wenatchee and Okanogan areas. Group B consists of independent water sources supplying irrigation to more or less isolated orchards.

The analyses in Group A show a very low salt content, as judged by comparison with many irrigation waters employed in western agriculture and, as stated above, fruit trees irrigated with these waters have maintained healthy growth and heavy production except in seepage areas. On the other hand, apple and pear trees irrigated with

FIG. 1. Carbonate concretions from the concentrated root areas of apple trees in "Se" orchard. Slightly enlarged.

waters of Group B have shown definite manifestations of vigor decline accompanied by varying degrees of chlorosis. The analyses show a higher concentration of salts than in the case of Group A, calcium and magnesium bicarbonate and sulfate predominating. It should be noted that sodium and particularly chloride values are low in relation to calcium, magnesium, sulfate, and bicarbonate in all of these waters, and this may be of importance in the interpretation of the effects of these waters on the deposition of carbonate in soil, as compared with waters having relatively higher amounts of sodium and chloride.

Orchard Descriptions

Since no long-term irrigation plots were available, field inspections were conducted in eight orchards irrigated with Group B waters and descriptions made of tree condition. Orchards included in this survey are among those which could be classified as free from influences other than the applied waters. Parent lime or other salt deposits, improper drainage, subsurface movement of waters from the outside, and abnormal cultural practices were carefully guarded against in the selection of orchards for description.

In the following descriptions, soil characteristics are only given general consideration, more emphasis being placed on tree growth and appearance. Fruit production records would contribute materially to the evidence, but the lack of accurate records over a long period of years and the natural and economic complications attending fruit production from season to season, tend to make the validity of such data questionable.

Orchard symbols in the descriptions correspond to water source designations of Group B, Table I.

"Cn" orchard:—13.5 acres of apple trees 23 years of age, and 2.5 acres of pears 21 years of age, irrigated throughout its history with water from an 81 foot well.

The orchard soil is alluvial, containing medium to fine sand interspersed with small rock fragments and gravel. Narrow illuvial streaks of fine sand mixed with silt at depths of 2, 4, and 5 feet. Coarse gravel below sixth foot. Vigorous effervescence with acid in the compact sandy silt strata but less pronounced in the other portions of the soil profile.

Of 111 Bartlett and Bosc pear trees, 103 exhibited varying degrees of chlorosis. The average degree of chlorosis in 1940 was 9 per cent, and this increased to 28 per cent in 1944. The evaluation of chlorosis was based on leaf counts and included unaffected as well as affected trees.

From 1940 to 1942 mild chlorosis symptoms were found in a high percentage of Delicious and Rome Beauty apple trees. Following fall applications of 25 pounds of ammonium sulfate per tree in 1942 and 1943, the health of the apple trees was greatly improved and a fair crop of well-developed fruits was harvested in 1944. Chlorotic leaves, however, were still prominently in evidence. This orchard has always been clean-cultivated but quack grass thrives in some portions.

"Se" Orchard:—A 150-acre apple orchard irrigated with water

from a small creek for 33 years. First foot of soil is a medium sandy loam with medium to coarse sand in the second, and very coarse sand and gravel at depths ranging from 3 to 6 feet. Loose, finely divided deposits of carbonate were present in the 2-, 3-, and 5-foot borings, and vigorous effervescence with acid occurred at all horizons. Calcareous incrustations were found in wooden water flumes and also numerous concretions in the soil in the concentrated root zones. These concretions were mainly cylindrical in shape and contained dead and mineralized tree roots. Very small hard grains or nodules were sometimes attached to small living roots. Upon analysis the concretions yielded 63 per cent total carbonates by weight, expressed as Ca CO_3. No hardpan was encountered in any of the borings.

Electrical conductance of a 1 to 5 water extract of this soil averaged 18 x 10^{-5} at 25 degrees C. The average pH value (A.O.A.C. moisture equivalent basis) was 7.7. Borings of unirrigated soil immediately adjacent to the orchard showed no effervescence at any soil depth, an average conductance of 3.6 x 10^{-5} and a pH value of 6.8.

Tree condition was studied during the growing season of 1943 and 1944. Winesap, Jonathan, and Rome Beauty trees in this orchard showed serious decline. The trees assumed a very thin appearance, with weak terminal and spur growths, small poorly developed leaves, small fruits, reddish colored bark, and considerable die-back. Chlorosis was prevalent throughout the orchard although entire trees were seldom affected. Chlorotic symptoms were most conspicuous in water sprouts, root suckers, and secondary terminal growths. Stayman Winesap trees growing beside devitalized Winesaps were quite vigorous and bore a heavy crop of well-developed fruits. According to the owner, production has been progressively reduced in all varieties with the possible exception of Stayman Winesap. Except for occasional chlorosis the leaves were green in color and scorching or other symptoms of salt injury were not in evidence. Cover crops consisted of scattered alfalfa plants and a profuse weed growth. Five acres of pear trees were included in the original planting but severe chlorosis necessitated their removal in 1939. Orchards within one mile and lying on the same general slope but irrigated with one of the water sources shown in Group A, Table I, were all in excellent vigor and showed none of the symptoms described above.

"Jn" Orchard:—27 acres of 14-year-old Delicious, Winesap, and Golden Delicious apple trees irrigated with water from a stream whose origin is known to be in a limestone region. The soil is well-drained, deep, uniform, fine silt loam underlaid with gravel. When dry, this soil is grey in color and extremely light and powdery. When wet, it is quite dark, compacts well, but does not become sticky. Rapid percolation was indicated in all parts of the orchard with the exception of one low-lying section where irrigation rills drained from two directions. Strong reactions for carbonate were obtained from 6 inches to 5 feet below the surface. Unirrigated soil adjacent to the orchard gave faint carbonate reactions at the fourth-foot level in lower elevations. Borings at two higher outside elevations showed no effervescence with acid.

During the growing seasons of 1943 and 1944 chlorosis was observed in 60 per cent of the Winesap and Delicious trees. The foliage area affected was not greater than 2 per cent in either year, however, characteristic decline symptoms were quite marked in Delicious and moderate-to-severe in Winesap. Delicious leaves were somewhat stunted in growth and partially folded at the mid-rib. This leaf folding appears to be a distinguishing trait of Delicious trees in early stages of vigor decline regardless of cause, but it has seldom been found to be so universally distributed as was the case in this orchard. In many Winesap trees the branches appeared almost devoid of spur leaves and on these trees fruits were quite small. Golden Delicious trees, on the other hand, were in excellent vigor, with large dark green leaves and a heavy crop of well developed fruit. These varieties were interplanted and all received the same cultural care. The soil management program included spring cultivation followed by a heavy cover crop of annual weeds.

Five acres of 4-year-old Delicious trees planted in old irrigated soil showed chlorosis in 14 per cent of the trees in 1944. About 4 per cent were moderately chlorotic throughout the tree while the rest displayed symptoms only in leaves arising from late summer secondary growths.

"Ca" Orchard:—A 35-acre apple orchard planted in 1910. From the time of planting until 1920 irrigation water was supplied by one of the sources listed under Group A, Table I. Since 1920, well water indicated in Group B has been substituted. The average water level in the well has been 30 feet from the surface during the irrigation season. Temperature of the water on August 31, 1944, was 12.5 degrees C.

The soil is very fine powdery silt underlaid with gravel at depths varying from 2 to 6 feet. Carbonate was present within the orchard in all soil horizons, although only faint effervescence could be detected where gravel was near the surface. A very rank annual weed and scattered sweetclover cover crop followed spring cultivation.

Tree condition records taken in the summer of 1943 and 1944 revealed that Winesap and Yellow Newtown apple trees growing in the deeper soils were in an extremely devitalized condition. These varieties had made practically no growth in either spurs or terminals and the foliage area was insufficient to produce a crop. Annual heavy applications of nitrogenous fertilizers failed to improve the growth status of these trees. Fruit-set in both years was very light and fruits on the tree did not attain sufficient size to harvest. Delicious trees interplanted with Winesap and Yellow Newtowns were also low in vitality but did not approach the critical condition of the latter. Golden Delicious trees in the same area were making good growth, had large healthy leaves and a good crop of fruit. A chlorotic condition of secondary terminal foliage and water sprout tips was prevalent throughout the entire orchard, except on Golden Delicious and a few trees of other varieties growing on the more shallow gravely slopes. Anjou pear trees in these gravely sections were also apparently healthy and free from chlorosis.

"Ck" Orchard:—6 acres of Winesap and Delicious apples and 4 acres of Bartlett and Anjou pear trees, 34 years of age, irrigated with one of the sources shown in Group A for the first 10 years and with well water (30-foot depth) the following 24 years. Mid-summer temperature of well water at orchard was 12.2 degrees C.

Soil is a grey silt loam mixed with fine sand and underlaid with gravel and large rocks at depths of 5 and 7 feet. Carbonate present in all horizons except the surface 6 inches, which is predominately loam. The cover crop consisted of scattered alfalfa plants and annual weeds.

Thirty-three per cent of the Bartlett and Anjou pear trees were chlorotic in 1944. Seven per cent were classified as severe, 9 per cent as moderate, and 14 per cent as slight. According to the owner, chlorosis was first noticed in 1939 and the number of affected trees and degree has progressively increased each year. Associated with chlorosis was a pronounced stunting of vegetative growth, and most fruits failed to attain sufficient size for marketing. Winesap and Delicious apple trees showed characteristic lack of vigor, small spur leaves, poor extension growth, and undersized fruits.

"Ln" Orchard:—2 acres of interplanted 12-year-old Delicious and Golden Delicious apple trees. Prior to 1936 the Columbia River provided water for irrigation, but from 1936 to 1943 spring water was used.

The first 2 feet of soil is rather uniform fine to medium sandy loam, and the third foot is medium sand. Gravel and coarse sand are generally found below the 3-foot level. Carbonate was present in the second and third foot of soil but effervescence was not so vigorous as in the case of the orchards described above. Sparse alfalfa and annual weeds constituted the cover crop.

When observed in 1943, the foliage of Delicious trees was very thin and tree vigor in general was low. Chlorotic symptoms were quite prevalent although the degree in terms of percentage of leaves affected was not great. Some trees were also affected with "little leaf." Fruit production in most of the trees was very low. Due to the owner's rather light fertilizer program, the low vitality of these Delicious trees might at first be ascribed as nitrogen deficiency. Golden Delicious trees, however, in the same planting did not show the same decline symptoms, and Delicious trees of the same age growing in other parts of the orchard, and receiving the same cultural treatments, but irrigated each year with Columbia River water, appeared to be in good vigor.

"Os" Orchard:—219 Bartlett and Flemish Beauty pear trees 22 years of age irrigated with surface spring water originating at about 200 foot elevation above the orchard. The soil in this orchard deviates from the great majority of soils of the Wenatchee-Okanogan orchard areas in that it contains a relatively high percentage of clay. The first foot is brown clay loam containing traces of carbonate. In the second foot the soil grades from a loam through a clay to a greyish-brown clay. The third and fourth feet are both heavy bluish-grey clay which is sticky and plastic when wet and exceedingly hard when dried. Small carbonate deposits were present throughout the profile.

The orchard is located on a steep hillside and has a good alfalfa cover crop.

In 1943, 80 trees were chlorotic, 20 of which showed 10 per cent of the foliage area affected; 44 trees with 30 to 50 per cent; and 16 trees with 70 to 90 per cent. The average percentage of chlorotic leaves per tree in 1943 was 14.3 ± 1.6 per cent. In 1944, 77 trees were chlorotic, 30 of which had 10 per cent of the foliage area affected; 39 with 30 to 50 per cent; and 18 with 70 to 90 per cent, for a general average percentage of 13.0 ± 1.6 per cent. One severely chlorotic tree was removed early in 1944 and is not included in the 1944 records.

"Mc" Orchard:—In 1940 this orchard consisted of 10 acres of 13-year-old Winesap and Delicious apple and Bartlett pear trees, irrigated with water from a 45- to 50-foot well. In 1941 the well water was abandoned and Columbia River water used during the past 4 growing seasons.

In 1940 test borings with a soil tube to depths of 10 feet indicated a very heterogenous alluvial soil mass, ranging from fine sandy loam to coarse sand and gravel. Small broken fragments of granite mixed with sand were found in one portion of the orchard. Thin strata of very fine sand and silt were intermingled from the third- to tenth-foot levels, the relative position of the strata within the profile varying from one location to another within the orchard. Strong tests for carbonate were obtained in horizons containing silt strata, moderate tests in the finer sand and loam, and only traces or negative tests in the coarse sand pockets. In 1944 practically all tests for carbonate were slight or negative in the first 3 feet, regardless of soil character. Slight-to-moderate effervescence was obtained at the fourth foot and beyond. A fairly heavy stand of alfalfa has been maintained in the entire orchard since it was planted.

The 1940 records of 230 apple trees revealed chlorosis to be present in 196 trees. The average leafage affected was 11.2 per cent. After irrigating 4 seasons with Columbia River water only 30 trees, of the original 230, showed chlorotic symptoms and then only on 1.3 per cent of the leaves of all the trees. Of 179 Bartlett pear trees all but 16 were chlorotic in 1940 and the affected leafage was 26 per cent. One hundred thirty-seven trees was subsequently pulled out and the remaining 42 trees, therefore, constituted the only basis for comparison. Thirty-four of these 42 pear trees had an average of 15.2 per cent of chlorosis in 1940, while the same group of trees exhibited chlorosis on 10 trees in 1944, with an average of only 2.9 per cent of the foliage involved.

Thus it appears that changing from well water to Columbia River water materially reduced the incidence of chlorosis in both apple and pear trees. It seems highly probable that within these 4 years sufficient carbonate was leached from the root zones to restore vigor in a high percentage of the trees.

Discussions and Conclusions

This report does not provide an opportunity for specific deductions relative to the quality of irrigation waters and the complex physical

and chemical changes resulting from their application to soil. It does suggest, however, that waters of compositions given in Group B, Table I, can be considered as objectionable for irrigating certain varieties of apple and pear trees if used over a relatively long period of years.

It is perhaps true that water with the salt concentrations shown in Group B may be regarded by some authorities as highly satisfactory for almost any irrigation purpose, but the presence of carbonate in the orchards studied indicates the rate of calcium and magnesium carbonate deposition to have greatly exceeded the rate of leaching in the soil areas described and with the irrigation waters used. The relatively low sodium content of these waters may partially account for more rapid precipitation, although other factors may also be operative.

Chlorosis, in varying degrees, was always associated with carbonate in the soil although no quantitative relationship was found between the percentage of carbonate in any of the horizons and the incidence or degree of chlorosis. Of importance, perhaps, is the fact that apple and pear trees tend to show a marked decline in vigor when irrigated for a number of years from wells, springs, or small creeks containing bicarbonates in concentrations of 200 p.p.m. or more. Apart from the complex factors involved in the causation of chlorosis, certain disturbances in the soil complex might be brought about which tend to limit the availability of certain nutrients and thus account for the low vitality in the trees. The formation of carbonate concretions on the surface of apple roots and the presence of minute carbonate nodules on small fibrous roots lend some support to such an assumption, although the possibility of direct injury or toxicity cannot be disregarded. This accumulation of carbonate on the surface of apple roots is suggestive that in fundamental studies on the effects of certain irrigation waters on plant growth and behavior, attention should be directed to the concentration or deposition of salts at the root-soil interfaces rather than to the percentage of salt in the whole soil mass.

Annual plants and leguminous cover crops appeared to thrive in all the orchards under observation. These plants are apparently quite tolerant to alkaline soil conditions as compared with fruit trees. Also, in the case of an apple or pear tree a substantial portion of the root system will probably occupy a particular soil mass for many years. Under arid conditions the build-up of carbonate from irrigation waters could, through evaporation, root absorption, or other processes, become quite concentrated in the occupied soil even though the salt content of the water may normally not be considered as excessive.

In the orchards described, chlorosis was the predominant disorder of Bartlett, Bosc, Anjou, and Flemish Beauty pear trees, and no evidence of varietal susceptibility or resistance was observed.

Chlorosis in apple trees was rather sporadic and only in rare instances was it found to be severe. A characteristic decline in vigor was pronounced in all apple varieties observed, with the exception of Golden Delicious. Winesap trees were lowest in vitality in all or-

chards. Where present, Yellow Newtowns were likewise markedly affected, followed by Delicious, Jonathan, Rome Beauty, and Stayman Winesap in somewhat the order of decreasing severity. Differences between Jonathan and Rome Beauty, however, were either too small or the observations insufficient for clear differentiation. No explanation for the apparently thrifty condition of all Golden Delicious trees can be advanced at this time, but if this variety does possess a specific tolerance to alkaline conditions its use may be of practical importance in establishing orchards where only high-bicarbonate waters are available.

In the "Mc" Orchard, marked improvement in chlorosis was apparent when Columbia River water was substituted for the well water previously used for irrigation. After four years, carbonate had been leached from the first 3 feet of soil and only slight effervescence with acid was evident in the fourth foot. Apparently, in coarse-textured soils with adequate drainage there is a possibility of restoring vigor in apple and pear trees by leaching with waters of low bicarbonate content.

A Rapid Method for the Determination of Chlorophyll in Apple Leaves

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PREVIOUS investigations conducted by this laboratory on the nutrition of McIntosh apple trees have been concerned largely with yields and nutrient deficiencies with respect to additions to the soil or tree of N, K, and Mg especially. Striking differences in leaf color were often obtained and it was considered desirable to evaluate quantitatively these differences. Accordingly, a rapid method for the determination of chlorophyll was devised. Although no new principle is involved, the procedure is well adapted to certain problems under investigation by us and is thought to be of sufficient value to be reported. The method is based on the fact that the strong absorption band in the red end of the spectrum for chlorophyll is not over-lapped by those of the carotenoid pigments.

EXPERIMENTATION

Extraction and Determination:—Discs 16.6 mm in diameter were cut from fresh leaves and placed immediately in 95 per cent ethanol. After some experimentation it was found convenient to use 30 discs (about 1 gram fresh wt.), one from each of 30 leaves, placed in 30–40 ml of solvent. The leaf tissue was left to stand in the solvent for 24 hours and then mixed in a Waring blendor for 3–4 minutes. The solution was then filtered into a 100 ml volumetric flask using a Whatman 44 filter paper and made up to volume by washing the pulp with several portions of solvent. The extract was read in a photoelectric colorimeter using a light filter which transmitted above 610 millimicrons. The colorimeter was standardized with solutions of pure chlorophyll. Eight to ten samples could be disintegrated, filtered and determined in an hour.

The values reported are milligrams of chlorophyll per sample of thirty discs 16.6 mm in diameter (130 sq. cms. for two sides). The fresh weight per unit area (data not presented) was considered unreliable, due to changes in water deficit and to difficulties of weighing under field conditions.

To reduce changes in composition of the chlorophyll, all samples were kept in the dark except during the operations of extraction and filtration. The laboratory was darkened while making chlorophyll determinations. Normal room temperatures prevailed. A number of other factors which had some bearing upon the values obtained were studied briefly.

RESULTS

Effect of Solvent upon Percentage Extraction:—Three solvents, methanol, 95 per cent ethanol, and acetone were selected because of their ready availability or for their property of dissolving readily the leaf pigments. The solvents were used without purification or dilution.

The percentage extraction was determined by disintegrating the sample in a Waring blendor for 3–4 minutes and filtering as noted above and then extracting the pulp a second time in the blendor, each time washing the pulp on the filter paper with about 65 ml. of solvent, the operations being the same for all samples. The final volume for each extract was 100 ml. The total amount of chlorophyll extracted in the two operations was taken as 100 per cent and that obtained in the first extraction was computed as a percentage of the total. The acetone extract filtered clear through a Whatman No. 44 paper but was cloudy when a No. 31 or 40 paper was used. The two alcohol extracts filtered clear through a Whatman No. 31 paper. Representative data showing the percentage extraction with these solvents are presented in Table I. Twelve samples of different total chlorophyll content were

TABLE I—EXTRACTION OF CHLOROPHYLL FROM McINTOSH APPLE LEAVES BY ACETONE, ETHANOL (95 PER CENT), AND METHANOL. AVERAGE OF 12 SAMPLES FOR EACH SOLVENT

Solvent	Chlorophyll—Mgs per 130 Cm² of Leaves			Per Cent First Extraction of Total
	First Extraction	Second Extraction	Total	
Acetone	2.10	0.26	2.36	89.0
Ethanol	2.21	0.13	2.34	94.5
Methanol	2.21	0.04	2.25	98.2
Diff. req. for significance, 1 per cent level	0.17	0.06	0.13	

extracted with each solvent. Those extracted with acetone varied from 1.92 to 2.77 mgs, those with ethanol from 1.72 to 2.77 mgs, and those with methanol from 1.65 to 2.95 mgs. Under the conditions imposed upon the solvents, acetone removed the least, methanol the most, with ethanol intermediate.[1] These results are similar to those reported by Fleischer (2).

Extraction Methods:—A number of methods proposed for chlorophyll determinations on fresh tissue, such as that of Johnston and Weintraub (3), involved grinding the tissue with sand and solvent in a mortar. This operation seemed especially tedious and was not compared with the method proposed here for disintegration of the tissue. The tissue was kept in the solvent for various lengths of time prior to blending and the ease and completeness of removal of chlorophyll noted. Fresh tissue required a minimum of 10 minutes blending with careful washing down of the pulp several times to attain a satisfactory removal of chlorophyll. Immersion of the tissue in methanol or ethanol for from 24 to 72 hours gave equally good results, and blending 3-4 minutes resulted in satisfactory extraction of chlorophyll. When acetone was used as the solvent, a longer blending time was necessary for extraction as complete as that made by the alcohols, even though the maximum time of immersion was allowed. Some of the data for ethanol are given in Table II. The differences found over

[1]A few extracts made with 1, 4-dioxane indicated a percentage extraction similar to that of ethanol.

TABLE II—EFFECT OF IMMERSION TIME IN (95 PER CENT) ETHANOL UPON AMOUNT OF CHLOROPHYLL FOUND IN McINTOSH APPLE LEAVES. AVERAGE OF 10 SAMPLES

Time in ethanol prior to blending, hours.....	0	5	17	24	48	72
Length of time blended, minutes	10	4	3	3	2	2
Chlorophyll, mgs	3.13	3.15	3.15	2.88	3.14	2.97

Difference required for significance 5 per cent level 0.19
1 per cent level 0.25

the 3-day period are not considered significant. This fact permits sampling in the field to be carried out over an extended period without undue changes in the chlorophyll content.

Calibration of Colorimeter:—The colorimeter was calibrated with solutions of a sample of chlorophyll *a* and *b* which had been prepared carefully and stored in the dark at a low temperature (4). Light transmittance was similar for extracts and standard solutions for wavelengths above 610 millimicrons, as measured on a quartz spectrophotometer[2]. A Corning No. 2412 light filter was used in the colorimeter. The purity of any sample of dried chlorophyll stored over a period of time may be in question (5). The values for chlorophyll reported here are considered as relative only.

Age of Leaf:—From time to time during the season, 30 shoots having at least eight leaves of normal size were selected from each of several McIntosh apple trees. The leaves were numbered consecutively 1 to 8, starting with the first average-sized basal leaf and taking them in order up the shoot. The two or three tip leaves were discarded. The first basal leaf from each of the 30 shoots made up Sample No. 1. Sample No. 2 was then taken from the second basal leaves and so on for the eight leaves. Thus there were eight samples of progressively younger leaves. Chlorophyll was determined as described above. The data presented in Fig. 1 show a decrease in chlorophyll with increasing age of leaf, and indicate that leaves should be selected from the middle portion of the shoot to obtain relatively comparable values for chlorophyll over a period of several weeks.

Representative Samples:—As was noted above, it was found convenient to limit a sample to 30 discs 16.6 mm. in diameter. The sampling error involved in this small sample can be evaluated from the data given in Table III. Ten 30-leaf samples were taken from a single tree, 6 discs being cut from each leaf to make a total of 60 samples of 30 discs each. The data show that the least difference for mathematical significance at the 5 per cent level is 0.09 mg. and 0.12 mg. at the 1 per cent level. Any one of the ten samples, except No. 4, is equally representative of the chlorophyll content for this tree on the date sampled. Other data not reported showed even less variation.

Chlorophyll Content of McIntosh Apple Leaves:—Data for the seasonal trend in chlorophyll for one of the orchards sampled in 1944 are presented in Fig. 2. Twenty 3-tree blocks had been under differ-

[2]The authors are indebted to Dr. G. H. Ellis of the U. S. Nutrition Laboratory, Ithaca, N. Y., for use of the spectrophotometer.

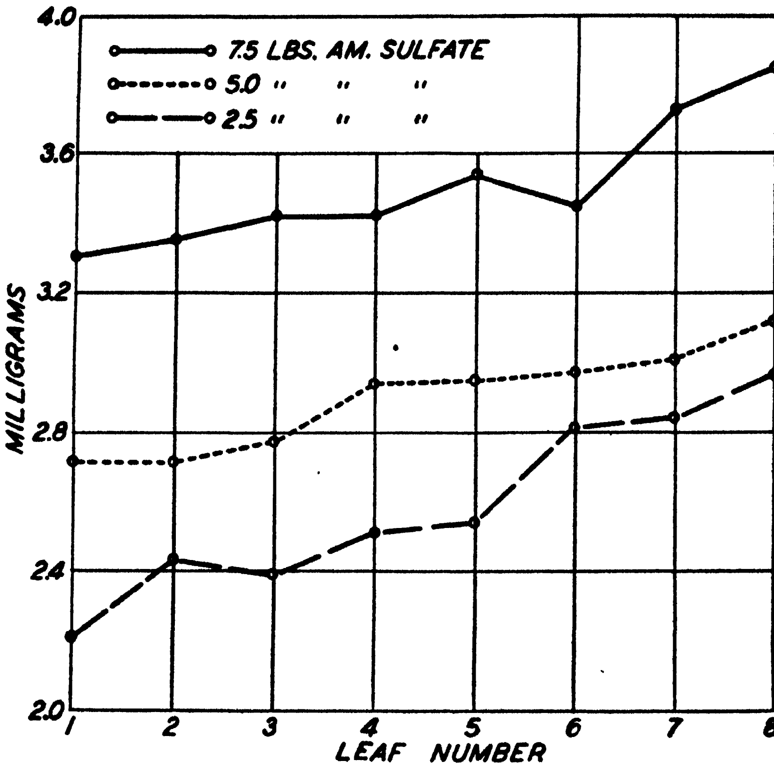

FIG. 1. Chlorophyll content of McIntosh apple leaves as influenced by position of leaf on the shoots. No. 1 leaf, first average sized basal leaf, others in numerical order up the shoot. Chlorophyll as mgs. per sample of 30 discs, 16.6 mm in diameter.

TABLE III—CHLOROPHYLL IN MCINTOSH APPLE LEAVES. THIRTY LEAVES PER SAMPLE, 6 DISCS 16.6 MM DIAMETER FROM EACH LEAF

Leaf Sample	Disc Number						Sample Average
	1	2	3	4	5	6	
	Mg	Mg	Mg	Mg	Mg	Mg	
1.	2.84	2.88	3.05	3.05	3.06	2.95	2.97
2.	3.04	3.05	3.01	3.01	3.22	3.04	3.06
3.	3.03	3.03	3.04	3.04	3.04	3.00	3.03
4.	2.70	2.81	2.66	2.66	2.91	2.70	2.74
5.	3.04	3.06	3.07	3.04	3.06	2.94	3.04
6.	3.01	3.19	2.87	3.15	3.06	2.95	3.04
7	2 95	3.01	2.92	2.76	2.76	3.14	2.92
8.	2.92	2.95	2.78	2.69	3.09	2.92	2.89
9.	3.00	2.92	2.92	2.92	2 92	2.86	2.92
10.	2.86	2.86	2.87	2.87	3.09	2.88	2.91
Disc. Av	2.94	2.98	2.92	2.92	3.02	2.94	2.95

Difference required for significance 5 per cent level 0.089
1 per cent level 0.118

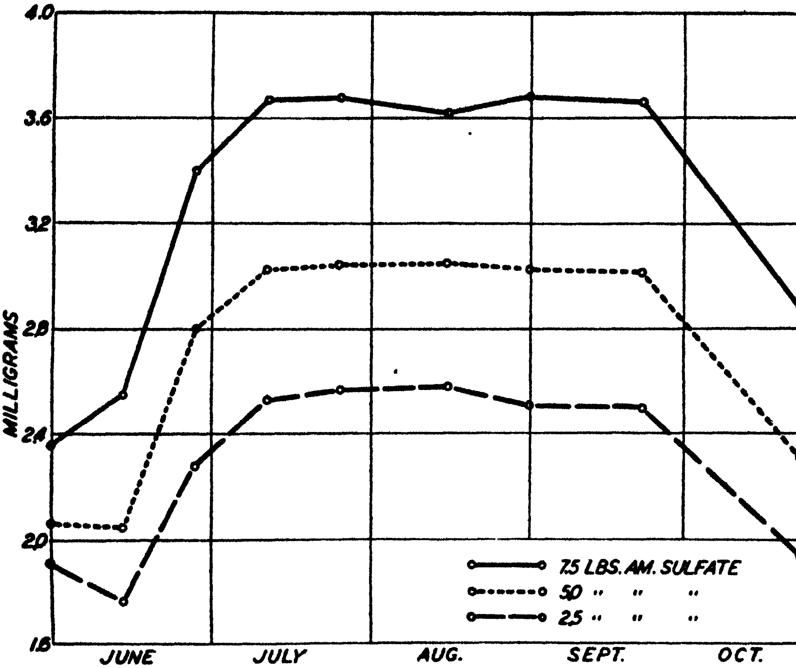

FIG. 2. Effect of nitrogen fertilizer upon chlorophyll content of McIntosh apple leaves. Chlorophyll as mgs. per sample of 30 discs, 16.6 mm in diameter.

ential nitrogen fertilizer treatment for the three years 1942–1944, the A tree in each block receiving annually 7.5 pounds of ammonium sulfate, the B tree 5.0 pounds, and the C tree 2.5 pounds. Samples of 30 leaves were taken from each tree on the dates noted. Chlorophyll was determined 24 to 48 hours later by the procedure described above, using 95 per cent ethanol as the solvent. The orchard is 23 years old and is planted on Dunkirk very fine sandy loam of good fertility and high soil moisture capacity. The orchard practice is excellent. A more complete description of this property has been reported previously (1).

The differences in chlorophyll between treatments are all highly significant at odds of 99: 1. As the graph shows, the chlorophyll content increased rapidly from the end of May to early in July and then remained fairly constant until after harvest. Samples of uninjured leaves taken October 23 following a hard freeze on October 22 showed a chlorophyll level roughly equal to that on May 30 for their respective treatments. The main feature of the data is the remarkably uniform level for each treatment for the 73-day period starting July 11, the height of the level following directly the fertilizer practice. Other data obtained on trees grown under considerably different climactic conditions indicated a somewhat similar seasonal trend.

As has been reported previously (1), the trees at the 7.5 pound level of fertilization have produced a smaller yield (not mathematically significant) than have the trees at the 5.0 pound level. Thus a luxury consumption of nitrogen is indicated for the trees at the highest fertilizer level, which seems to be shown with remarkable accuracy by the chlorophyll content of the leaves. The data indicate that chlorophyll determinations may be a useful diagnostic aid in evaluating the nitrogen nutrition of apple trees. Studies of these possibilities are now in progress. Improvements in the method for determining chlorophyll are contemplated.

Summary

The method proposed provides a rapid and accurate means of determining chlorophyll in plant tissue. Transmittance of light above 610 mμ is measured in a photoelectric colorimeter by using a suitable filter, comparison being made against readings obtained with pure chlorophyll. Certain precautions as to filtering, sampling, decomposition by light, and the effect of solvent upon extraction are pointed out. The seasonal trend in cholorphyll for one orchard is discussed in relation to yields and fertilizer practice.

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Nitrogen Absorption of Ringed Orange Trees in Sand Culture

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Although numerous experiments involving the effect of ringing on the transport of nitrogen have been performed, little information is available regarding the effect of ringing on absorption of nitrogen by the root system. This problem is of some importance in horticulture because trees are sometimes girdled by rodents and because of the occasional practice of ringing to induce fruit setting or flowering. Shamel and Pomeroy (3) have shown that ringing is particularly effective in increasing fruit set on the Washington Navel orange. This paper reports the results of ringing experiments on two series of orange trees grown in sand culture.

Procedure and Results

The trees used in these experiments were: series A, the sweet orange variety Parson Brown on sour orange stock; and series B, the variety Valencia on sour orange stock. They were grown in 8-gallon crocks of quartz sand, outdoors, at Orlando, Florida. During absorption periods of about 5 days each week, several liters of solution were displaced by the addition of tap water followed by fresh nutrient solution, Hoagland's (1), daily. At the end of each absorption period, the crocks were thoroughly leached. The total leachate from each crock for each period was collected in 5-gallon bottles, measured, and sampled for analysis. The absorption of nitrogen per tree was determined by the difference between the average nitrate nitrogen content of the leachate from two treeless control crocks and that of the leachate from the cultures.

Nitrate nitrogen was determined colorimetrically by the phenoldisulphonic acid method. Agreement between nitrate applied and that recovered from the treeless control crocks was good, and indicated that reduction of nitrate in the crocks was negligible.

Series A

The seven trees of series A had been used in a nutrition experiment that was terminated just before the ringing experiment was started. These trees, which had been grown in the crocks for 2 years, had been subjected to alternate periods of starvation and of feeding with complete nutrient solution for the preceding 18 months. They were consequently rather large for the crocks and were pot-bound. The trees were divided into two groups; four trees comprising one group were ringed, while the second group of three trees served as nonringed controls.

The average daily rate of absorption of nitrogen per tree during each absorption period is given in Table I, and also index values of absorption by the ringed trees. These index values are the ratios of

TABLE I—THE ABSORPTION OF NITRATE NITROGEN BY RINGED AND NON-RINGED PARSON BROWN ORANGE TREES

Absorption Periods	Non-Ringed (Mg per Day)	Ringed (Mg per Day)	Index (Non-Ringed = 100)	Ringing Treatments
Mar 16–20 . .	345	319	92	None
Mar 21–26. . .	372	318	85	None
Mar 29–Apr 3	243	216	89	None
Apr 5–10 . .	317	218	69	Single cut through bark, Apr 5
Apr 12–17. .	317	246	78	
Apr 19–24 . . .	314	275	87	
Apr 26–May 1	311	284	91	
May 3–8 .	262	183	70	¼ inch ring of bark removed May 3, wound covered
May 10–15 .	297	216	73	
May 17–22. .	270	194	72	½ inch ring removed and scraped May 23, wound covered
May 23–29 . .	256	157	61	
May 31 Jun 5	264	135	51	Rescraped, wound covered, June 3
Jun 7–12 . . .	202	74	37	
Jun 14–19 .	Lost	Lost	—	Rescraped and left bare, June 19
Jun 20–25	267	117	44	
Jun 27–Jul 2. .	182	27	15	
Jul 5–10.	183	48	26	

ringed tree to non-ringed tree absorption rates multiplied by 100. Nitrogen absorption by each tree was determined during three absorption periods before any of the trees were ringed. On April 5 one group was ringed by making a single knife cut through the bark of the trunk but without removing any bark. This method of ringing has been used on Washington Navel oranges (3). From the index values of Table I it appears that the absorption rate of the ringed trees was probably reduced slightly during the first week after ringing (period, April 5–10); but during the next two periods, April 12–17 and April 19–24, the absorption rate apparently increased. During the third period after ringing, April 26–May 1, the index value was as high as before ringing. On May 3 a ¼-inch ring of bark was removed from the trunk of each ringed tree, and the wound was covered with a grafting compound. This type of ringing resulted in a more prolonged reduction in the absorption rate than did the single knife cut, but the rings were completely bridged by wound tissue in 20 days. On May 23 the rings were widened to ½ inch and the wound tissue was scraped away. To prevent bridging over by wound tissue, the rings were scraped on June 3 and June 19, and on the latter date the wood was left bare of grafting compound.

It is apparent from the index values that from May 23 to the termination of the experiment on July 10 there was a fairly steady, slow decline in the rate of absorption of the ringed trees.

SERIES B

In July, fourteen 3-year-old Valencia orange trees on sour orange stock were removed from the nursery, heavily pruned, and set in crocks where they were maintained until a good leaf surface and a vigorous root system had developed. After two preliminary absorption periods, seven trees were selected for ringing and seven for non-ringed controls. On September 20 ¾-inch rings of bark were removed from the trunks of the ringed group. These rings were left without protection to prevent bridging of the rings by wound tissue.

The average daily rate of nitrogen absorption per tree during each absorption period and the index values for series B are given in Table II. The index values suggest that ringing effected a considerable

TABLE II—THE ABSORPTION OF NITRATE NITROGEN BY RINGED AND NON-RINGED VALENCIA ORANGE TREES

Absorption Periods	Non-Ringed (Mg per Day)	Ringed (Mg per Day)	Index (Non-Ringed = 100)	Ringing Treatments
Sep 5–10	53	39	73	None
Sep 14–19	51	47	92	None
Sep 21–26	75	41	55	¾ inch ring removed, wound not covered Sep 20
Sep 27–Oct 2	54	21	39	
Oct 4–9	46	13	28	
Oct 11–16	84	11	13	
Oct 18–23	Lost	Lost	—	
Oct 25–30	87	10	11	

reduction in the rate of absorption of these trees during the first period after ringing. The rate declined rapidly during the next three periods, but probably remained at about the same low level from October 11 to 30, when the experiment was terminated. The loss, during a hurricane, of the samples of October 18-23 makes somewhat uncertain the course of absorption during the latter part of the experiment. It is apparent, however, that the response to ringing in series B was more marked than in series A.

DISCUSSION AND CONCLUSIONS

It is apparent from these experiments that ringing that allowed rapid healing or bridging of the ring by wound tissue, reduced absorption of nitrogen for only a brief period of time. After trees were ringed by a single knife cut, the absorption rate apparently returned to normal in about 2 weeks. When ringing was done in such a manner as to prevent repair of the wound, a reduction in absorption was observed during the first 5 days after ringing and the rate continued to decline or remained at a low level for the remainder of the period of observation — in series A about 8 weeks, and in series B, six weeks. In view of the rapid healing over of a single knife cut and the presumably prompt resumption of translocation of nitrogen and carbohydrate, it is difficult to explain the pronounced effects on flowering and fruit setting often observed.

It is generally maintained that in normal trees most of the nitrate nitrogen is reduced in the roots and converted to organic nitrogen compounds. If this process is not appreciably interfered with in ringed trees and if it may be presumed that organic nitrogen is not transported across a ring, then most of the absorbed nitrogen would accumulate in the roots and trunk below the ring and might be expected to interfere with further nitrogen absorption. It appears unlikely, however, that accumulation alone would result in such a rapid reduction in absorption rate as was observed.

It seems likely that a number of factors enter into the effect of ringing on nitrogen absorption. Hoagland and Broyer (2) in reporting

their own investigation and reviewing that of Steward on salt absorption by roots, emphasize the important effect of the metabolic state or activity of the root cells, the salt content, and the amount of carbohydrate available for respiration and other metabolic activities in the root. On the basis of the principles elucidated by these workers, it may be supposed that absorption in the ringed trees was reduced as a result of at least the following factors: the prevention of the downward movement of carbohydrate and growth substances past the ring, the depletion or exhaustion of reserve carbohydrate and possibly growth substance in the roots, the accumulation of nitrogen compounds below the ring, and the reduction in growth and metabolic activity of the roots as a consequence of shortages of elaborated food and growth substance.

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Cambial Activity and Starch Cycle in Bearing Orange Trees

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In a previous paper (2) observations on the starch cycle, with slight reference to growth activity in young orange trees, were reported. The present paper reports the results of a much more comprehensive study of cambial activity and fluctuations in starch content of full-bearing orange trees.

Materials and Methods

The conclusions here presented are based on three series of microscopic and microchemical observations made on materials collected as follows:

1. Between March 7, 1940, and May 3, 1940, Azouni (1) collected branches, at approximately weekly intervals, from a large 11-year-old sweet orange seedling tree. In so far as possible, upright growing branches from 6 to 14 feet in length, with few or no large laterals, were chosen. Samples were taken in basipetal sequence, the distance between samples varying from a few inches at the tip to 1 or 2 feet at the basal end.

2. Between February 21, 1938, and March 1, 1940, 36 Valencia orange trees, eight years old at the time collections were begun, were excavated at 3-week intervals. These trees had been propagated by budding carefully selected seedlings of a sweet orange with buds from a single parent tree (3). They were vigorous, healthy, large for their age, and were bearing good crops all in the same crop phase. Samples representing all parts of these trees were collected at the time of excavation and were preserved in alcohol for later study.

3. Between February 1, 1944, and October 15, 1944, samples were collected from representative parts of another large seedling sweet orange tree—a sister tree to the one used by Azouni—at intervals of from 2 days to about 3 weeks, depending upon the amount of cambial activity.

The materials used for the first and last series of observations were sectioned, stained and studied immediately after collection. Those for the second series were kept in the preservative until after the collections were completed, when all were sectioned and studied.

Two combinations of stains were used for studies of cambial activity. For temporary mounts, phloroglucin-hydrochloric acid was used and for permanent preparations safranine and fast green. For observations of starch content, the standard technique of staining with iodine, potassium iodide, and mounting in glycerine was employed. This stain also proved to be very satisfactory for observations of cambial activity because of differential staining of the new and old tissues.

Observations and Discussion

Since these three series of observations supplement or corroborate each other, the conclusions derived from them will be presented without specific reference to any particular set of collections.

In studying cambial activity in the orange tree, one is impressed by two characteristics: (a) The rather striking irregularity in the time of initiation of cambial activity in similar parts of the same tree, and (b) the relatively slow basipetal progression of cambial activity from twigs to roots.

The orange tree under our climatic conditions charactertistically produces three flushes of new growth during the year. The spring flush, which at Los Angeles occurs during February, March and April, consists of both vegetative and blossom-bearing new shoots. The summer and autumn flushes normally consist wholly of vegetative shoots. In the spring cambial activity was first evident in many of the twigs which bore the new shoots shortly after the shoots began to grow. In some, however, no cambial activity was evident until after the new shoots had completed their length growth, from four to six weeks after growth began.

Following initiation in the twigs, cambial activity appeared to proceed slowly basipetally. Clear evidence of a definite pattern of progression was not observed because of the great irregularity in time of initiation, especially in the small branches. The amount of cambial activity present in a branch at this stage appeared to be dependent mainly upon the amount of new shoot growth beyond the point of observation.

This irregularity, together with the slow rate of progression, results in considerable variation in the time of initiation of cambial activity in the larger branches. Notwithstanding this, by about the middle of April cambial activity was quite general throughout the scaffold branches and trunk. Some evidence of earlier activity in the trunk was observed, suggesting that the cambium may become active in this region independently of activity in the branches above. Two or three weeks later it was evident in the main root. Progress in the roots was much slower than in the branches. No certain evidence of activity in the primary roots could be detected until after the middle of June, in the lateral roots until late in July, and in the small roots until the last week in September. More extensive collections might have disclosed cambial activity in some of the small roots as early as August immediately following the cessation of the summer flush of shoot growth.

Cambial activity was of quite short duration in the twigs, ceasing about the middle of May and proceeding basipetally, apparently in the same sequence as initiation, and continuing in the trunk until about December 15. Below ground cessation was in reverse direction to that of initiation. Activity ceased first in the small roots about November 1, approximately one month after initiation, and proceeded acropetally. Some activity was evident in the main root as late as December 1.

Partial rings of varying thickness, and very irregular in occurrence, in the xylem both above and below ground suggest cyclic cambial activity. However, no clear evidence of such was observed except in the twigs which produced new shoots during one or more of the flushes of growth. In these there was unmistakable evidence of renewed cambial activity for short periods during and shortly following shoot growth. That one might expect to find evidence of cyclic growth in the small roots, at least of young trees, is suggested by the work of Crider (5) who reported that the roots of young citrus trees produce three quite distinct flushes of length growth each season, alternating with those of the top. Our own unpublished observations confirm those of Crider.

As the tree increases in age, the cambium of the permanent scaffold parts seems not to be much influenced by the cyclic growth of twigs and roots. Our present observations suggest that the behavior of the young roots may also be modified as the tree increases in age, as no evidence of diameter growth of small roots was observed except in the autumn during the interval between the summer and fall flushes of top growth.

Observations on the diameter growth of trunks of Washington navel orange trees at Upland, California, by Halma and Compton (6) are in accord with our observations of cambial activity. These authors report continuous diameter growth from February to December, most of the increase occurring between April 15 and November 30. In two of the three years of their investigations, two definite peaks of activity are evident in September of one year and October of the other. Such differences in rate of diameter growth may account for the partial and incomplete growth rings mentioned above.

The fact that the trees involved in the 2-year collection period were producing alternately large and small yields all in the same crop phase (Table I), afforded an opportunity to observe that the size of crop on the tree had little or no influence on the time of initiation or cessation of cambial activity. Counts of new xylem cells indicated greater cambial activity in the trunk and main roots during the year of light crop.

Observations on starch accumulation and depletion, in the main, confirm those previously reported for young trees (2). Considering the tree as a whole, starch accumulated during the winter to a maximum content just prior to the initiation of growth activity in the spring. It then decreased gradually to a minimum in the autumn and early winter. These fluctuations in amount of starch were confined almost entirely to parts adjacent to actively growing shoots and roots and to regions close to the cambium. Except for deposition in new tissues, the amount of starch in the xylem of main branches, trunk and large roots appeared to remain practically constant throughout the year. In the bark of above ground parts and that of small roots, small though detectable reductions in starch content occurred during the period of cambial activity. Surprisingly little change was observed in the starch content of the outer bark of the larger roots which was heavily stored with starch at all times. These observations do not

correspond with those previously reported for young trees (2) in which wide fluctuations in the starch content of root bark was recorded. This situation may indicate relatively less root growth in the old than in the young tree.

Disappearance of starch was never complete in all tissues even in the twigs and branches bearing growing shoots which suggests that either photosynthesis of adjacent leaves supplied sufficient carbohydrate for active growth, blossoming, and fruit setting, or, as suggested in the previous paper (2), the leaves serve as an important reservoir of these materials. No microchemical observations of leaves were made in these studies and as yet no quantitative data are available.

A reduction in the amount of stored starch was evident in the twigs and small branches shortly after the beginning of spring cycle shoot growth. Following this, starch disappeared from the phloem and in some cases apparently from the outer xylem of adjacent branches. Such disappearance coincided with, or slightly preceded, evidence of cambial activity in these parts. Some doubt exists regarding an actual reduction in amount of starch in the outer xylem owing to the impossibility of being certain that the particular tissues involved were completely filled before the initiation of growth activity. Little or no starch was observed in current season xylem while the cambium was still active. After cambial activity had ceased, starch was deposited in a rather regular pattern from the inside toward the periphery. Deposition in the xylem rays preceded that in the parenchyma. If not completely filled during the season in which it was laid down, the filling appeared to be completed the following season before starch was deposited in new xylem.

Because of the pronounced alternate bearing of the valencia orange in the coastal districts of Southern California, samples were collected over a 2-year period. The average yield for a 5-year period of the trees in the block from which these trees were excavated is presented in the Table I.

TABLE I—Yield of Valencia Orange Trees in Experimental Block

Average Yield Per Tree				
1936 (Pounds)	1937 (Pounds)	1938 (Pounds)	1939 (Pounds)	1940 (Pounds)
210	94	310	137	368

The effect of fruiting on starch content was definite but quite localized, being confined largely to the twigs and small branches.

These parts were considerably higher in starch content in the spring of 1939 than in the spring of 1938 and 1940. Presumably this was due to the relatively light crop harvested in 1939. This crop was set in the spring of 1938 and was the only fruit on the trees during the period between the harvesting of the large crop of 1938 in July and August and the setting of the 1940 crop in the spring of 1939.

A similar effect of fruiting on starch storage in avocado trees has previously been reported (4).

SUMMARY

Observations of cambial activity and starch cycle in full-bearing orange trees appear to support the conclusions which follow.

Cambial activity is first evident in the spring in twigs and small branches bearing new shoot growth.

Initiation in other parts is very irregular but appears to depend upon relatively slow basipetal progression both above and below ground.

In the above ground parts, cessation of cambial activity is in basipetal sequence, the same as initiation. In the roots, it is acropetal, which is opposite to that of initiation.

Fluctuations in starch content are confined to tissues close to the cambium and to parts adjacent to actively growing shoots or roots. Other parts contain large quantities of starch at all times.

Heavy fruiting results in a reduced starch content in the above ground parts, confined mainly to the twigs and small branches.

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Nitrogen in Bearing Orange Trees

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In a previous paper (1), data and conclusions regarding the distribution and seasonal fluctuations of total nitrogen in the Valencia orange tree were presented. The conclusions then advanced were based mainly on a study of 15 young trees collected during a period of 1 year. The availability of NYA assistance during 1938–1939 afforded the opportunity to undertake a much more comprehensive study of the composition and seasonal fluctuation in the constituents of mature bearing Valencia orange trees. We herein present data and conclusions relating to the nitrogen content of 36 bearing trees, collected at intervals of 3 weeks throughout a 2-year period.

Materials and Methods

The trees used for this study have been referred to in previous reports (3, 4, 5). They were temporary trees in a double planted block which was set out in May, 1930. In propagating them special care was taken to secure uniformity in genetical composition by budding very rigidly selected (presumably nucellar) seedlings of a sweet orange with buds all from one Valencia orange tree.

The orchard soil in which these trees were grown is a fertile, recent aluvial loam, of indefinite depth, derived from sedimentary rock (Yolo Series), somewhat coarser at depths below 12 to 15 inches than at the surface. The fertility and uniformity of the orchard soil together with the uniformity in genetical constitution resulted in a group of vigorous, healthy trees which were large for their age and unusually uniform in size and bearing behavior.

For convenience and accuracy in determination of gross weight and composition, a uniform harvesting procedure was adopted which involved dividing each tree into 14 or 15 arbitrarily chosen fractions, 9 of which were further subdivided through separation of wood and bark. Fractionation was either on the basis of diameter or of the character of growth (Table I). Records of the fresh and dry weights of all parts and of the number of leaves were kept. Aliquots of each fraction and subfraction were preserved for subsequent chemical and microchemical determinations. Except for a record of amount, the fruit was ignored in these studies.

As much as possible of the root system of each tree was recovered by carefully raking over all the soil as it was removed — some 50 to 60 tons. This was not a difficult operation because most of the roots were in the sandy loam soil below the 12- to 15-inch depth. As soon as recovered, the roots were placed between layers of damp burlap. Before fractionation all soil was removed by washing the roots on a screen with a stream of water under high pressure.

Except in the tree row where damage might have been done to adjacent permanent trees, the excavation was made wide enough (about 24 feet) and deep enough (usually 5 to 6 feet, though occasionally

TABLE I—DISTRIBUTION OF DRY WEIGHT AND NITROGEN IN AN "AVERAGE" BEARING VALENCIA ORANGE TREE

Fraction	Total Weight (Grams)			Percentage Nitrogen		Percentage of Total in Sub-fraction			
						Including Leaves		Excluding Leaves	
	Fresh	Dry	Nitrogen	Fresh Weight	Dry Weight	Dry Weight	Nitrogen	Dry Weight	Nitrogen
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Leaves									
—	41,619	15,910	331.41	0.78	2.08	16.84	45.33	—	—
Twigs									
—	6,702	3,546	37.35	0.56	1.06	3.75	5.11	4.51	9.34
Shoots									
—	9,480	5,564	36.69	0.39	0.66	5.89	5.02	7.08	9.18
Lateral Branches (0.75 to 1.5 Cm)									
Bark	3,037	1,476	18.69	0.61	1.26	1.56	2.56	1.88	4.68
Wood	8,751	5,806	16.39	0.18	0.28	6.15	2.24	7.39	4.10
Tertiary Branches (1.5 to 3.0 Cm)									
Bark	3,144	1,501	18.81	0.60	1.25	1.60	2.57	1.91	4.71
Wood	14,827	9,651	25.14	0.17	0.26	10.22	3.44	12.28	6.29
Secondary Branches (3.0 to 6.0 Cm)									
Bark	2,457	1,130	14.33	0.58	1.27	1.20	1.96	1.44	3.58
Wood	18,096	11,721	30.49	0.17	0.26	12.41	4.17	14.92	7.63
Primary Branches (Over 6.0 Cm)									
Bark	1,323	609	7.73	0.58	1.27	0.64	1.06	0.78	1.93
Wood	13,638	8,850	22.83	0.17	0.26	9.37	3.12	11.27	5.71
Trunk									
Bark	845	359	4.36	0.52	1.22	0.38	0.60	0.46	1.09
Wood	12,242	7,740	21.25	0.17	0.27	8.19	2.91	9.85	5.31
Main Root									
Bark	743	335	5.64	0.76	1.66	0.35	0.77	0.43	1.41
Wood	8,985	5,515	22.86	0.25	0.41	5.84	3.13	7.02	5.72
Large Roots (Over 2.5 Cm)									
Bark	2,283	985	17.19	0.75	1.74	1.04	2.35	1.25	4.30
Wood	9,623	5,937	24.58	0.26	0.41	6.29	3.36	7.56	6.15
Intermediate Roots (0.8 to 2.5 Cm)									
Bark	3,233	1,285	20.54	0.63	1.59	1.36	2.81	1.64	5.14
Wood	5,466	3,072	14.50	0.27	0.47	3.25	1.98	3.91	3.63
Small Roots (0.3 to 0.8 Cm)									
Bark	2,181	861	13.11	0.61	1.52	0.91	1.79	1.10	3.28
Wood	1,948	1,041	6.25	0.32	0.61	1.10	0.85	1.33	1.56
Rootlets									
—	2,105	820	10.11	0.48	1.25	0.87	1.38	1.04	2.53
Feeder Roots									
—	2,892	749	10.92	0.38	1.43	0.79	1.49	0.95	2.73
Total...	175,870	94,622	732.04	—	—	100.00	100.00	100.00	100.00

10 to 12 feet) to recover most of each lateral or tap root. In the tree row the excavation was made halfway to the adjacent permanent tree. All roots in this area, whether from the excavated or the adjacent permanent tree, were recovered.

To justify this procedure, the following assumptions were made: (a) that since the permanent trees were part of the same population

planted at the same time and receiving identical care, they should be similar in composition to the excavated tree; and (b) that the roots of the excavated tree extending beyond the excavation would approximately equal in amount those of adjacent permanent trees which invaded the excavated area. In all cases the only roots involved were so small that they could not materially affect either the amount or composition of the samples. Large enough crews of men were available to complete the operations associated with the excavation and fractionation of a tree in from 24 to 36 hours.

The samples for microchemical observations were preserved in 50 per cent alcohol. Aliquots for macrochemical determinations were dried at 70 degrees C in a ventilated oven, after which they were ground in a Wiley mill and stored in double sealed cans. For the present study, duplicate determinations of total nitrogen were made on aliquots of the dried and ground material by the modified Kjeldahl-Gunning method.

Data and Discussion

It is obviously neither possible nor necessary to present all the data relating to each of the 36 trees used in this study. Rather, we have chosen to present the data in somewhat condensed form. The values in Table I were obtained by averaging comparable figures for fresh and dry weight of all the trees. This table, in addition to indicating the gross composition of an "average" tree, shows in column 1 the fractionation employed. Because, as indicated in this table (columns 5 and 6), adjacent similar parts of the tree are nearly alike in their nitrogen content, we have combined a number of fractions to give the values presented in Table II, which shows the distribution of nitrogen in each of the 36 trees. The following combinations of fractions were made: twigs and shoots, branch and trunk bark, branch and trunk wood, root bark, and root wood. Rootlets and feeder roots were for this purpose considered as bark.

Inspection of the data presented in Tables I and II reveals that the leaves, which account for between 12 and 20 per cent of the total dry weight of the tree, contain from 40 to 50 per cent of all the nitrogen in the tree. The twigs and shoots, which represent about one-tenth of the total dry weight, contain about 10 per cent of the nitrogen. The trunk and branches, which together make up half the weight of the tree, contain from 20 to 30 per cent of the nitrogen, approximately half of which is in the bark, a fraction which represents only about 5 per cent of the total dry weight. The roots, which constitute about one-fifth of the total tree weight, contain from 15 to 20 per cent of the nitrogen, half or more of which is in the bark, a fraction which also represents about 5 per cent of the dry weight of the tree.

The primary purposes of this study were to determine (a) the magnitude of the seasonal changes in the nitrogen content of all parts of the Valencia orange tree, and (b) the effect of fruiting on depletion and accumulation of nitrogen in the full bearing tree.

The calculated values given in columns 19 and 20 of Table II,

TABLE II—DISTRIBUTION OF TOTAL WEIGHT AND NITROGEN IN VALENCIA ORANGE TREES AND THE RELATIONSHIP BETWEEN NITROGEN AND DRY WEIGHT AT INTERVALS THROUGHOUT A 2-YEAR PERIOD

Date of Collection	Total Weights (Grams)			Percentage of Total in Above Ground Parts											Percentage of Total in Roots				Percentage Total Nitrogen on Total Dry Weight	
				Blossoms		Leaves		Twigs and Shoots		Branches and Trunk				Bark		Wood			
										Bark		Wood							
	Fresh	Dry	Nitrogen	Dry Weight	Nitrogen	Dry Weight	Nitrogen	Dry Weight	Nitrogen	Dry Weight	Nitrogen	Dry Weight	Nitrogen	Dry Weight	Nitrogen	Dry Weight	Nitrogen	Including Leaves	Excluding Leaves
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
2/26/38	156302	73366	692	0.14	0.51	20.69	51.54	11.69	11.17	4.89	7.13	40.66	12.68	4.04	7.27	17.91	9.70	0.94	0.58
3/19/38	124775	62736	524	0.24	0.87	18.49	46.27	9.39	10.07	4.86	7.53	44.48	15.18	5.02	9.90	17.53	10.15	0.83	0.55
4/7/38	130861	70887	553	0.11	0.40	18.22	48.62	9.76	10.20	5.44	8.49	45.23	14.64	5.11	9.12	16.11	8.55	0.78	0.49
4/30/38	119098	64870	499	—	—	19.47	50.08	10.56	10.61	4.33	6.71	40.91	13.80	5.03	8.36	19.71	10.44	0.77	0.48
5/21/38	155156	84953	678	—	—	18.65	49.04	11.24	11.63	4.77	7.21	43.39	14.19	4.45	8.35	17.49	9.58	0.80	0.50
6/13/38	153829	82712	613	—	—	19.56	49.86	12.55	11.89	5.19	8.17	44.77	15.13	4.08	7.38	13.83	7.57	0.74	0.46
7/5/38	154822	91815	694	—	—	20.20	47.56	13.82	12.22	6.59	9.98	39.39	12.70	5.92	10.45	13.59	7.09	0.76	0.50
7/25/38	167825	87323	650	—	—	20.08	52.05	10.24	10.18	5.43	8.77	47.91	15.79	4.23	6.73	12.08	6.48	0.74	0.45
8/15/38	177199	93554	693	—	—	17.89	47.31	9.00	9.09	5.14	8.70	45.25	14.97	4.83	9.58	17.86	10.35	0.74	0.47
9/6/38	179844	94156	777	—	—	18.28	48.28	10.44	9.07	4.99	8.15	46.96	15.58	4.37	9.55	14.94	9.37	0.82	0.52
9/24/38	175674	95470	710	—	—	18.92	49.61	8.99	8.83	5.32	9.04	47.63	16.18	3.58	7.62	15.52	8.72	0.74	0.46
10/14/38	179410	96040	679	—	—	18.03	48.20	9.88	9.49	5.25	9.00	46.30	15.95	3.77	7.86	16.76	9.50	0.71	0.45
11/4/38	161679	87530	651	—	—	18.84	48.87	8.89	8.57	5.20	8.61	45.73	15.60	4.84	9.22	16.48	9.13	0.74	0.47
11/25/38	178764	99893	749	—	—	15.88	44.06	8.97	9.05	5.75	9.74	47.73	16.53	5.28	10.95	16.35	9.67	0.75	0.50
12/15/38	182076	96925	720	—	—	16.01	42.03	9.80	10.49	5.87	10.31	46.55	16.65	5.40	10.91	16.32	9.61	0.74	0.51
1/6/39	165688	91776	668	—	—	15.18	42.35	11.99	12.92	5.67	9.71	47.14	16.96	5.05	9.96	14.96	8.10	0.73	0.49
1/27/39	155907	85339	653	—	—	13.91	40.16	8.57	10.46	6.06	10.15	47.85	16.80	6.02	12.71	17.59	9.72	0.76	0.53
2/17/39	144547	80551	645	—	—	14.31	38.61	6.59	8.26	6.46	10.61	49.19	17.35	6.46	14.21	16.98	10.96	0.80	0.57
3/9/39	160718	89830	709	0.15	0.81	15.02	39.85	10.02	11.46	5.22	8.77	43.86	15.32	6.10	12.83	19.62	10.99	0.79	0.56
3/31/39	147421	83812	647	0.68	3.55	15.62	39.25	8.14	9.64	5.58	9.41	44.92	15.74	6.05	11.72	18.98	10.70	0.77	0.53
4/20/39	182314	94971	766	3.85	17.15	14.10	31.30	9.60	9.73	4.89	7.71	44.05	13.96	5.81	10.18	17.67	9.97	0.81	0.51
5/11/39	209818	105545	783	0.51	1.86	15.84	45.30	9.40	9.75	5.35	8.66	47.71	15.48	5.76	10.57	15.41	8.41	0.74	0.47
6/1/39	184000	95106	708	—	—	18.75	46.41	9.40	9.61	5.13	7.93	42.92	13.59	5.85	10.34	17.93	9.69	0.74	0.47
6/22/39	191593	99960	774	—	—	16.40	39.52	10.73	10.79	5.09	8.29	45.16	15.37	5.93	11.55	16.67	10.14	0.77	0.53
7/14/39	202227	107499	780	—	—	17.37	46.68	9.25	9.66	5.59	9.33	47.20	16.19	5.19	9.48	15.37	8.66	0.72	0.47
8/3/39	188827	99778	730	—	—	17.27	48.16	9.19	9.87	4.97	8.34	45.96	15.37	5.04	9.49	17.54	8.77	0.73	0.46
8/24/39	204547	113515	921	—	—	17.63	48.92	8.43	8.68	5.22	8.28	47.86	15.76	4.71	9.15	16.13	9.21	0.81	0.50
9/14/39	207513	115987	853	—	—	16.37	46.73	9.81	9.89	5.12	8.64	48.83	16.73	4.13	9.56	15.70	8.45	0.73	0.47
10/5/39	192136	91048	654	—	—	12.11	36.77	8.77	10.00	5.85	10.18	50.49	19.33	6.57	13.89	16.20	9.83	0.72	0.52
10/26/39	168713	88783	680	—	—	13.68	38.91	9.27	11.37	5.35	9.24	48.77	17.90	5.19	12.21	17.72	10.37	0.77	0.54
11/16/39	218547	122430	993	—	—	16.53	47.49	8.17	9.41	5.64	9.01	49.12	17.05	3.75	8.13	16.76	8.91	0.81	0.51
12/7/39	205402	114186	904	—	—	13.95	39.89	8.51	9.36	5.45	9.44	50.42	19.13	4.69	10.96	16.94	11.22	0.79	0.55
12/28/39	181560	96333	730	—	—	16.34	45.22	10.24	10.61	5.37	8.85	46.47	16.21	4.72	10.13	16.82	8.98	0.76	0.49
1/18/40	190177	102056	847	—	—	16.31	45.77	9.53	10.26	5.46	8.30	47.69	16.34	5.33	10.61	15.66	8.72	0.83	0.54
2/10/40	200391	111926	966	—	—	16.91	48.41	9.92	9.83	5.12	7.63	45.50	15.28	5.17	10.05	17.37	8.80	0.86	0.53
3/1/40	218188	126113	1110	—	—	17.42	47.09	8.73	10.56	5.45	7.91	48.47	16.08	4.49	9.54	15.42	8.82	0.88	0.56

together with the data presented in Figs. 1 and 2 indicate the degree of individual tree variability and show the seasonal changes in nitrogen content of the whole tree and its parts. Seasonal fluctuations in the percentage of nitrogen in the various parts of the tree are illustrated by the graphs in Figs. 1 and 2. Except in leaves, bark, small

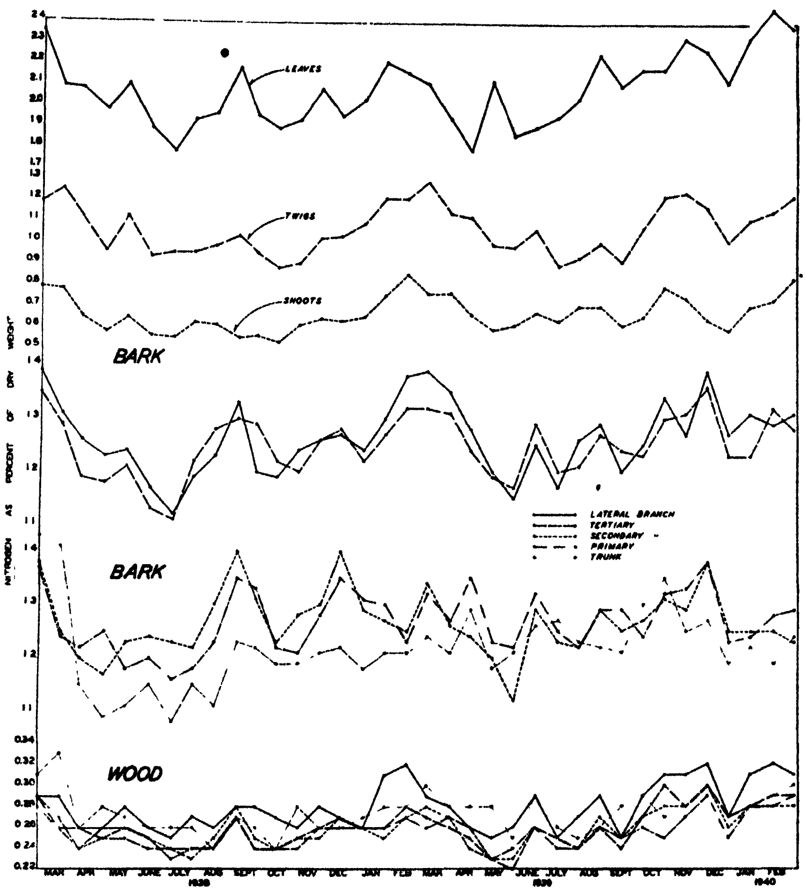

FIG. 1. Seasonal fluctuations in the nitrogen content of above-ground parts of bearing Valencia orange trees. Nitrogen calculated as a percentage of the dry weight.

branches and roots which are mainly bark, changes in the nitrogen content were not large. Seasonal changes in the nitrogen content of these trees were essentially the same as those previously reported for young trees (1). The tree contained more nitrogen just before the initiation of growth activity in the spring than at any other time of the year. This is more definitely shown by the figures in columns 19 and 20 of Table II than by the graphs in Figs. 1 and 2. Some of the graphs of bark samples suggest a maximum nitrogen content about December

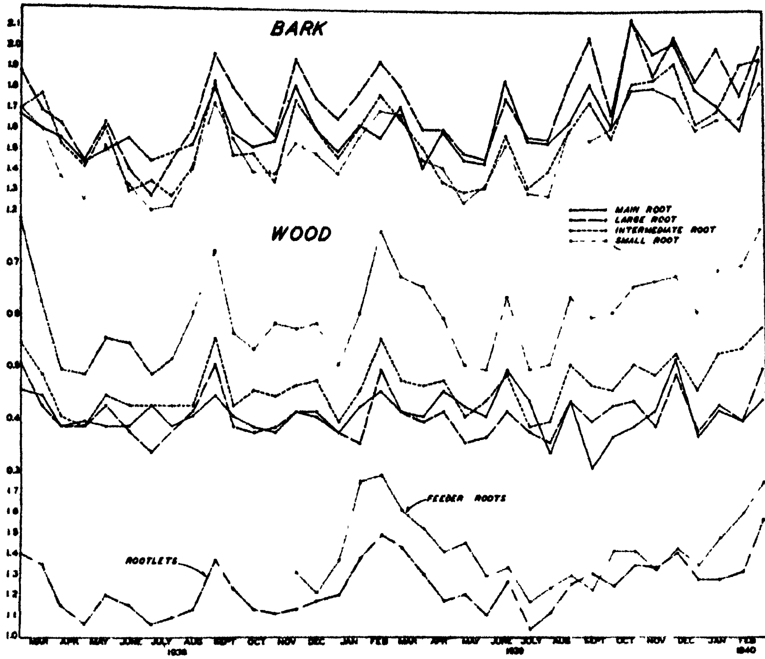

FIG. 2. Seasonal fluctuations in the nitrogen content of roots of bearing Valencia orange trees. Nitrogen calculated as a percentage of the dry weight.

1, followed by a decrease. A similar situation was obtained in the root bark of the young trees previously studied (1). The apparent reduction between December and February in both instances probably is the result of deposition of starch and possibly other carbohydrates in these tissues, which occurs during this period (5). The decrease may of course be real, resulting from a shift of nitrogen to other parts.

During the period of active growth, blossoming, and fruit setting in the spring and early summer, a decrease in the nitrogen content of all parts of the tree occurred. This decrease may in part be attributed to losses in shed leaves, blossoms, and young fruits, and also in part to utilization by the fruit of both the new and old crops. Determinations of such losses were not made a part of these studies. However, previous studies have shown that substantial amounts of nitrogen are lost to the tree through the shedding of blossom parts (1) and young fruits (2) as well as in the mature fruit (1). A study to determine the amount of nitrogen lost in shed parts of some of the permanent trees in the same block is now in progress.

The decrease in nitrogen content continued until late June and early July, 1938 and early June, 1939 (Figs. 1 and 2 and Table II, columns 19 and 20). During the summer and autumn of each year,

there was, notwithstanding rather wide fluctuations in amount of nitrogen, a gradual increase to the mid-winter maximum.

Because the periods of increase and decrease of nitrogen in the main correspond with periods of starch accumulation and disappearance (5), it is probable that the changes in nitrogen content are actually greater than are indicated by our data. As yet we have no quantitative data to indicate the changes in dry weight produced by deposition and removal of constituents other than nitrogen. If, however, as is probable, such changes parallel and exceed those of nitrogen, they will tend to mask the fluctuations in nitrogen content.

We are unable to definitely relate the short period fluctuations in nitrogen content or individual tree differences to either tree behavior or orchard management practices. The effect of fruiting is not clearly evident in either the graphs or the tables. The trees were bearing alternately large and small crops all in the same crop phase (4, 5). It is possible that the slightly lower level and the greater diversity in the nitrogen content of the trees during the summer and autumn of 1938 than during the summer of 1939 resulted from the larger crop of that year, part of which was not harvested until November 1.

The data indicate a generally lower level of nitrogen in relation to dry weight in the trees during the autumn and winter following the heavy crop of 1938 than during the corresponding periods following the light crops of 1937 and 1939. Observations of tree behavior, together with our studies of starch content, cause us to doubt that the figures portray the actual situation in the tree. In years when a large crop is harvested the trees are likely to be carrying a light new crop. They will then produce much new length growth during the summer and autumn growth periods and will bloom profusely the following spring (columns 5 and 6, Table II). When they are in the opposite crop phase, carrying a larger crop of immature fruit, they produce little new growth and a light bloom. When carrying a light crop of immature fruit the trees accumulate more starch than they do when they are in the opposite crop phase (5). Apparently as much or more nitrogen is utilized in the production of new growth including leaves, or is stored, by the trees carrying a light crop, as is required by the fruit on trees carrying a large crop of immature fruit. Such storage as does occur is masked by the increase in dry weight.

There appears to be no direct relationship between orchard management practices and the nitrogen content of the trees involved in this study. During the 2-year period of collection, nitrogen was applied as follows: February 26, 1938, one pound per tree in fish meal; September 6, 1938, one-half pound in dairy manure; June 5, 1939, one-half pound in sulfate of ammonia; July 15, 1939, one-half pound in sulfate of ammonia; August 28, 1939, one-half pound in dairy manure; August 29, 1939, one pound in sulfate of ammonia. The summer and autumn applications were made before an irrigation, the winter applications before the last winter rains. A similar program has been followed throughout the life of the trees.

No determinations were made of the nitrate concentration in the soil during the course of the collections. Because of the rather liberal

applications of nitrogenous fertilizers and because the trees have never shown symptoms of nitrogen deficiency, we assume that an adequate supply was available at all times.

The analytical results show that the nitrogen content of trees collected shortly after applications of quickly available nitrogenous fertilizers was no higher, and in some instances lower than that of those collected before the application. Notwithstanding the fact that there appears to be no immediate effect of fertilizer applications on the nitrogen content of individual trees, the generally higher level of nitrogen in the trees during late 1939 and early 1940 than in the corresponding period of 1938 and 1939 may have resulted from the more liberal applications of nitrogen during the summer and autumn of 1939 than during the same period of 1938 — two and one-half pounds as compared with one-half pound per tree. Earlier work (1) had led to the conclusion that additional applications of nitrogen to a soil in which the nitrogen supply was adequate did not result in an increase in the nitrogen content of leaves or branches of Valencia orange trees. As mentioned above, we consider it probable that in the present instance the higher values for nitrogen were the result of less dry weight of tissues because of a lower starch content (5).

The other orchard operation which might conceivably influence the nitrogen content of the tree is irrigation. There is, however, no evidence in the present study of any influence of period of application of water on the nitrogen level in the tree. Since the moisture content of the orchard soil was maintained above the wilting range and since, as we have indicated above, the nitrate supply in the root zone was almost certainly not a limiting factor, we should not expect to find an effect of irrigation on the nitrogen content of the tree.

Our present investigation was too gross and the period of collection too short to permit drawing definite conclusions regarding the relationship between tree behavior, orchard management practices, and the composition of the tree. More detailed studies to determine the effects of blossoming, growth, fruit production, fruit removal and regulation of nitrogen supply on each other and on the composition of the tree are now in progress.

Summary and Conclusions

Thirty-six bearing Valencia orange trees were excavated at intervals of 3 weeks throughout a 2-year period. Determination of the total fresh weight and moisture content of arbitrarily chosen fractions and subfractions were made and aliquots preserved for future chemical and microchemical studies. The present paper reports the results of a study of total nitrogen in these trees. The data suggest the following conclusions regarding distribution and seasonal fluctuations in the nitrogen content of full bearing Valencia trees.

1. Nearly one-half the nitrogen content of the tree is in the leaves; approximately one-tenth in the twigs and shoots; about one-fourth in the branches and trunk, nearly half of which is in the bark; and somewhat less than one-fifth in the roots, at least half of which is in the bark.

2. Except in the leaves and bark, fluctuations in the nitrogen content of the tree are not large.

3. A maximum nitrogen content occurs in the tree just prior to the initiation of growth activity in the spring. New growth, blossoming and fruit setting result in shifts in location and a decrease in amount of nitrogen through losses in shed leaves, blossoms and young fruits resulting in a minimum nitrogen content about mid-summer.

4. Fruiting does not produce direct measurable effects on the nitrogen content of the tree. An indirect effect is suggested because of the inverse relationship between the amount of new growth and the quantity of fruit on the tree.

5. Applications of nitrogenous fertilizers to soil in which the nitrogen supply is high apparently does not result in an immediate increase in the nitrogen content of the tree.

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Boron Content in Almond, Olive and Walnut Trees

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THE boron content of soils (5) and of date palms (4), avocado (3) and citrus trees (6) have been previously reported. Materials for analysis were obtained not only in the field but also from controlled solution cultures. Among other symptoms in citrus there was a marked vein splitting that resulted from the excessive accumulation of sugars (7). It was also reported (6), and since then confirmed, that vein splitting also occurs in leaves of magnesium-deficient cultures in which boron is adequate. It was further pointed out that the water-solubility of boron in monocots (date palms) is higher than that in dicots (citrus, avocado and other trees). The results now being presented were obtained with the leaves and fruits of almond, olive, and walnut trees.

Almond

A severe tipburn is frequently encountered in the leaves of almond trees not only in the Banning area but also in the Riverside area and the suggestion is often given that possibly boron is deficient. Since boron has not been found lacking in the soils at Riverside for the growth of other fruit trees, it is doubtful that a deficiency of boron is the cause of the tipburn. In Table I the leaves affected with tipburn show a slight reduction in boron content which may be a result rather than a cause for the tipburn, for no reduction in boron content occurs in the husks. Much of the boron in the dry matter of almond leaves is water insoluble. However, in the dry matter of the husk (the outer coat of the fruit) large concentrations of water-soluble boron may occur. Even the shells and kernels may contain considerable boron. Fruits of the Non-Pareil variety from San Luis Obispo contained .014 to .017 milligrams of boron per kernel whereas an average kernel of the Ne Plus Ultra variety contained .018 milligrams of boron.

Olive

Striking response was obtained (15) from boron applications to the soil in areas near Oroville in Butte County. A number of leaf and fruit samples were obtained from olive trees in the Oroville district and also from healthy olive trees in areas in which the available boron in the soil is adequate but not excessive.

Olive seedlings were obtained from the Mission olive orchard at the Citrus Experiment Station. These seedlings were grown for more than a year in culture solutions in some of which boron was omitted. When as much as 1 part per million of boron was supplied, the leaves were large and dark green, the shoots were long and the extensive root system was white or light in color. When Pyrex glass cylinders (5 gallon capacity) were used and boron was not otherwise added to the culture solution, the seedlings were in fair health although growth was somewhat retarded. Evidently the boron requirements

TABLE I—BORON CONTENT IN THE DRY MATTER OF ALMOND LEAVES AND FRUITS

Portion of Tree	Date of Collection	Variety	Location	Boron in Dry Matter (Ppm) Water Soluble	Water Insoluble	Total
Leaves	Oct. 19, 1942	Ne Plus Ultra	San Luis Obispo*	6.00	32.04	38.04
Husks				34.80	19.17	53.97
Shells				10.27	11.52	21.79
Kernels				—	—	24.10
Leaves	Oct. 22, 1942	Ne Plus Ultra	Davis*	11.70	41.85	53.55
Husks				400.00	40.54	440.54
Shells				83.36	19.12	102.48
Kernels				—	—	57.75
Leaves	Aug 6, 1936	Ne Plus Ultra	Banning R13, T5; Healthy tree	10.69	29.35	40.04
Leaves			Banning R14, T3; Severe tipburn	4.66	26.93	31.59
Husks			Banning R13, T5	21.88	16.88	38.76
Husks			Banning R14, T3	21.34	15.90	37.24
Leaves	Oct. 22, 1942	Non-Pareil	Davis*	9.45	34.38	43.83
Leaves	Aug. 6, 1936	Non-Pariel	Banning R2, T10, Healthy tree	6.05	28.30	34.35
Leaves			Banning R2, T3, 4, 5; Severe tip-burn	5.99	24.38	30.37
Husks			Banning R2, T10	24.05	12.34	36.39
Husks			Banning R2, T3, 4, 5	28.04	14.59	42.63
Leaves	Oct. 19, 1942	Non-Pariel	San Luis Obispo**	5.29	27.85	33.14
				8.12	28.50	36.62
Husks				29.00	16.13	45.13
				31.88	15.94	47.82
Shells				12.85	17.40	30.25
				16.35	20.06	36.41
Kernels				—	—	15.59
				—	—	17.70

*Collected by E. F. Serr, Extension specialist in deciduous fruits.
**Two different samples of leaves, husks, shells and kernels.

were being met fairly well from the boron given off from the Pyrex glass, for when such plants were transferred to cut-off (10 gallon capacity) glass carboys that previously were used for acid storage, or were transferred to Wearever Aluminum kettles with the same type of culture solutions as were previously used, the injurious effect of a lack of boron on the growth of the plants was very soon evident. The new leaves were dwarfed in size as shown in Fig. 1 A. Growth soon ceased and the leaves progressively back from the tip of the shoot became increasingly pale in color. Finally the leaves became desiccated and turned brown while still attached. In these young seedlings no zonate pattern was observed between the living basal portion of the blade and the burned tip (15), for in these plants the entire leaf turned pale uniformly throughout the blade. Infrequently a leaf was found in which the leaf showed tipburn. When these boron-deficiency leaf effects became pronounced, the twigs died back and showed protuberances and internal necrosis in the bark as described by Scott, Thomas and Thomas (15).

Regardless of the boron supply, a reduction in the calcium content of the solution from 159 to 16.2 or to 5.4 parts per million was accompanied by a yellowing of the blade beginning at the tip of the leaf as shown in Fig. 1,B. Cultures were first grown with boron and

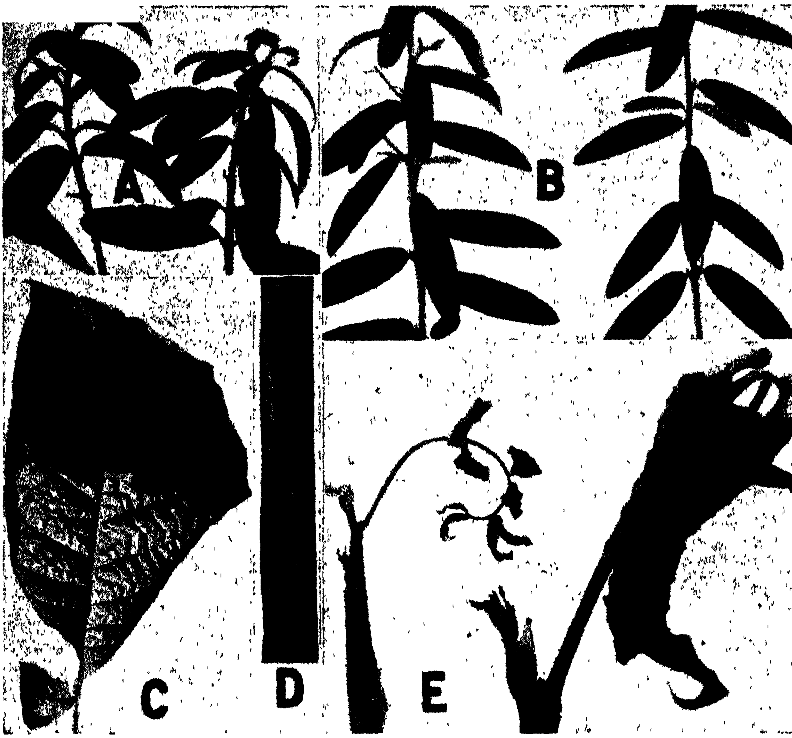

FIG. 1. A, Cessation of terminal growth in seedling Mission olive plants in a culture solution lacking boron; leaves progressively smaller near the tip of the shoot, becoming pale green, followed by desiccation and browning. B, Yellowing of tip portion of olive leaves accompanying low calcium in the culture solution. C, Terminal leaflet of a boron-deficient walnut seedling: veins distinct; vein islets and entire leaflet curled and brittle. D, Splits in the rachis (leaf stalk) of boron-deficient walnut leaves. E, Retardation and death of the new growth of walnut shoots resulting from boron deficiency.

calcium present and the boron later was omitted in some cultures while in others the calcium was lowered and in still others the boron was omitted and the calcium lowered. The lowering of the calcium was definitely associated with the yellowing (chlorosis) of the tip portion of the leaves. In the absence of boron the roots were dwarfed and dark brown with very few laterals. When calcium was reduced the roots also became darkened. The presence of boron tended to retard the progressive injury resulting from the reduced calcium.

Olive leaves obtained from orchard trees usually contained relatively small amounts of boron. The trees in the Oroville area (1) responded to boron applications to the soil (15). The leaves of trees in such areas showed extremely low water-soluble boron in the dry matter (Table II). The dry matter of young twigs obtained with

TABLE II—BORON CONTENT IN THE DRY MATTER OF OLIVE LEAVES AND FRUITS

Sample No.	Date of Collection	Location	Conditions	Boron in Dry Matter (Ppm)			
				Leaves		Fruit	
				Water Soluble	Water Insoluble	Pulp	Seed
1	———	Oroville†	No treatment	4.11	9.65	——	—
2	June 24, 1943	Oroville	No treatment	2.99	9.88	——	—
3	Sept. 30, 1943	Oroville	No treatment	•0.51	6.85	3.51; 4.44	2.81
4	Nov. 10, 1942	Reedley	Healthy tree	19.76	25.08	——	—
5	Dec. 26, 1941	Riverside	Irrigated; no fertilizer	14.38	15.88	25.38	—
6	Dec. 26, 1941	Fallbrook‡	No fertilizer	13.20	17.54	20.20	—
7	Dec. 26, 1941	Fallbrook‡	Fertilizer	17.58	18.43	26.60	—
8	Dec. 26, 1941	Fallbrook	Purple spots on fruits	9.29	20.48	28.04; 26.71	—
9	Dec. 26, 1941	Fallbrook	Healthy tree	——	——	23.30	—
10	Dec. 26, 1941	Fallbrook	Abscission of diseased leaves and fruits; cracks in pulp	——	——	14.59; 16.20	—
11*	Nov. 10, 1942	Reedley	Healthy tree	7.12	21.31	——	—
12*	Nov. 10, 1942	Lindsay	Healthy tree	11.32	19.43	——	—
13*	Nov. 10, 1942	Orange Cove	Healthy tree	5.54	19.93	——	—
14*	Sept. 1942	Hemet	Trees dying back	5.52; 6.60	14.20; 15.02	——	—

*Manzanillo variety; remainder are Mission olive trees.
†Samples from the Oroville area were kindly supplied by Mr. C. E. Scott and Mr. H. P. Everett.
‡These are adjoining orchards.

sample No. 2 contained 2.04 parts per million of water-soluble and 9.88 parts per million water-insoluble boron, whereas in the young twigs of sample No. 3 the values were 1.05 and 5.40 parts per million respectively. The fruits in sample No. 3 were green and pitted and also were malformed (15). The pulp of one affected olive in sample No. 3 contained .0032 milligrams boron whereas the seed contained .00176 milligrams. The soil in the orchard at Riverside from which sample No. 5 was collected contained 1.000 parts per million available boron (air-dry soil basis) in the first foot and 0.795 in the second foot. Soil from orchard No. 7 contained in the first twelve inches 3.005 and in the next six inches 1.166 parts per million of available boron respectively.

The boron content of the pulp of the olive fruits from Oroville was very low when compared with that in fruits obtained elsewhere. The fruits in sample No. 10 were obtained from trees affected with a severe fungous leaf spot that resulted in a considerable amount of defoliation. The leaves of the trees in the Hemet area (sample No. 14) are fairly low in boron and while they warrant tests of boron applications to the soil, they are not appreciably lower in boron than are the leaves of healthy trees from Orange Cove.

The addition of fertilizer to one of the adjoining orchards at Fallbrook is evident in the color of the foliage of the two orchards when viewed at some distance. Total including nitrate nitrogen determinations were conducted for the dry matter of leaves of trees in the unfertilized and fertilized orchards (Nos. 6 and 7) and the percentages found were 0.155 and 0.221 respectively. These values are less than one-tenth of those found in healthy mature citrus leaves.

The percentages of calcium, magnesium and potassium in the dry matter of the leaves were also determined. The water-solubility values are given in Table III. The olive leaves from the low boron trees at Oroville show very low calcium values that support the view that calcium and boron are in some manner related (9, 16). Low calcium in solution cultures, as previously mentioned, was accompanied by the chlorosis of the tip portion of the leaf blade, a condition referred to in boron deficiency symptoms in the field (15).

TABLE III—WATER SOLUBILITY OF CA, MG, AND K IN THE DRY MATTER OF OLIVE LEAVES

Date of Collection	Location	Soil Treatment	Ca in Dry Matter (Per Cent)		Mg in Dry Matter (Per Cent)		K in Dry Matter (Per Cent)	
			Water Soluble	Water Insoluble	Water Soluble	Water Insoluble	Water Soluble	Water Insoluble
June 24, 1943	Oroville	Boron-deficient tree; no treatment	0.100	1.146	0.058	0.093	0.856	0.078
Dec. 26, 1941	Fallbrook‡	No fertilizer	0.125	1 520	0 059	0.079	0.755	0.123
Dec. 26, 1941	Fallbrook‡	Fertilizer	0.135	1 480	0 061	0.088	0.820	0.150
Dec. 26, 1941	Riverside	Irrigated; no fertilizer	0.164	2 171	0.108	0.122	0.730	0.111
Nov. 10, 1942	Lindsay	*	0.176	1.946	0.101	0.118	0.786	0.066
Nov. 10, 1942	Orange Cove	*	0.140	2.075	0.079	0 101	0.793	0.090

*Manzanillo variety; remainder are Mission olive trees.
‡These are adjoining orchards.

The aqueous suspension of finely ground dried leaves of the Mission variety filtered very rapidly with the application of slight suction when the filter paper was supported by a cone. In contrast, the filtration was extremely slow with leaf material of the Manzanillo variety. In this latter variety the water-soluble fraction puffed vigorously upon gentle ignition after the fraction had been evaporated to dryness. This suggested the possibility that the leaves of the Manzanillo variety are richer in pectins or sugars than those of the Mission variety. The sugar content of olive fruits has been reported by Nichols (11), while the presence of sugar in olive leaves was pointed out by Power and Tutin (12).

Healthy olive leaves of the Mission variety contained the following percentages of reducing sugars and total (calculated as reducing) sugars respectively in the dry matter: Riverside, irrigated but not fertilized orchard, 1.66 and 3.71; Fallbrook, (dark purple spots on fruits), 1.72 and 3.44; Fallbrook adjoining orchards: no fertilizer, 2.39 and 5.57; fertilizer, 1.60 and 2.66. More sugars were present in leaves from trees in orchards where fertilization was not practiced. Healthy olive leaves of the Manzanillo variety contained the following percentages of reducing and total (calculated as reducing) sugars respectively in the dry matter: Orange Cove, 4.42 and 7.68; Lindsay, 4.63 and 7.68, while for leaves of trees showing die-back at Hemet the values were 5.51 and 10.47.

WALNUT

Water-soluble and -insoluble boron values were determined in the husks of walnut fruits of various varieties (2) collected in orchards in the Chino area where boron is not excessive. As shown in Table IV, much of the boron in the dry matter of walnut husks is water insoluble. Variations in the boron content in the different varieties are probably related to the age of the fruit because the flowering and maturity vary with the different varieties.

TABLE IV—BORON IN WALNUT HUSKS OF DIFFERENT VARIETIES COLLECTED AUGUST 24, 1935, NEAR CHINO

Variety	Number of Fruits	Boron in Dry Matter					
		Water Soluble		Water Insoluble		Total	
		Ppm	Mgm per Husk	Ppm	Mgm per Husk	Ppm	Mgm per Husk
Franquette	25	2.82	0.008	6.26	0.017	9.08	0.025
Seedling	25	4.32	0.010	12.67	0.028	16.99	0.038
Neff	27	5.27	0.016	12.45	0.038	17.72	0.054
Klondike	26	6.75	0.018	12.63	0.032	19.38	0.050
Placentia	25	5.39	0.013	14.50	0.036	19.89	0.049
Ehrhardt	25	6.40	0.012	17.50	0.033	23.90	0.045
Ware	25	8.20	0.021	17.56	0.044	25.76	0.065
Eureka	30	9.31	0.021	17.28	0.039	26.59	0.060
Payne	28	8.74	0.022	19.84	0.050	28.58	0.072

Some of the boron in the dry matter of the shells of walnut fruits is water soluble as shown in Table V. The total boron as a percentage in the dry matter of the kernels is less than that in the shell or husk. The boron content of walnut fruits from high boron areas such as Moorpark, differs from that in fruits from healthy areas such as Riverside in that the boron in the kernel and husk only is affected by the excessive boron. In the husk nearly half of the boron is water soluble under conditions of excessive boron in the soil.

TABLE V—BORON IN MATURE WALNUT FRUITS

Variety	Number of Fruits	Boron in Dry Matter (Ppm)						
		Kernels	Shells			Husks		
		Total	Water Soluble	Water Insoluble	Total	Water Soluble	Water Insoluble	Total
Fruits Collected September 25, 1942, in Field 5, Block A, C.E.S. Riverside								
Eureka	18	11.63	3.74	9.84	13.58	5.52	16.13	21.65
Payne	18	9.66	5.02	10.34	15.36	4.62	24.18	28.80
Placentia	18	7.58	4.90	9.38	14.28	8.37	24.11	32.48
Fruits Collected September 25, 1942, in High Boron Area at Moorpark								
———	20	16.33	5.73	8.87	14.60	39.21	40.67	79.88

The solubility of boron in the dry matter of walnut husks of various ages is given in Table VI. The water-soluble boron decreases between July 19 and August 20, both as a percentage in the dry matter and as total grams of water-soluble boron per husk. During this period a decrease also occurs in the total grams of water-insoluble boron per husk.

TABLE VI—BORON IN WALNUT HUSKS OF DIFFERENT AGES. FRUITS COLLECTED NEAR ELSINORE

Date of Collection (1935)	Number of Fruits	Fruit Size (Cm)	Boron in Dry Material					
			Water Soluble		Water Insoluble		Total	
			Ppm	Mgm per Husk	Ppm	Mgm per Husk	Ppm	Mgm per Husk
			Payne Variety					
June 7	44	3.2×3.4×4.0	4.64	0.010	13.74	0.028	18.38	0.038
June 18	32	4.0×4.2×4.8*	4.31	0.012	10.54	0.028	14.85	0.040
July 19	23	3.9×4.1×4.6	7.90	0.022	9.95	0.028	17.85	0.050
August 20	22	4.0×4.1×4.6	4.33	0.010	11.69	0.027	16.02	0.037
			Placentia Variety					
May 29	54	3.5×3.5×4.0	4.25	0.006	13.61	0.020	17.86	0.026
June 18	22	3.7×3.9×4.4	4.99	0.013	9.56	0.024	14.55	0.037
July 19	23	4.0×4.2×4.7	6.71	0.018	12.70	0.035	19.41	0.053
August 20	22	4.0×4.2×4.7	3.97	0.009	13.13	0.031	17.10	0.040
			Eureka Variety					
June 18	47	Variable†	5.59	0.012	12.09	0.026	17.68	0.038
July 19	25	4.1×4.0×5.3	18.02	0.074	9.10	0.038	27.12	0.112
August 20	22	4.0×3.8×5.0	16.39	0.044	10.29	0.028	26.68	0.072

*Shells becoming hard.
†Shells very soft.

TABLE VII—BORON IN WALNUT TREES GROWS IN SOLUTION CULTURES AND IN THE FIELD

Portion of Tree	Date of Collection	Source of Material	Boron in Dry Matter (Ppm)		
			Water Soluble	Water Insoluble	Total
		Solution Cultures			
Leaves	December 16, 1938	Boron-free	11.78	24.15	35.93
Trunk	December 16, 1938	Boron-free	5.71	8.19	13.90
Roots	December 16, 1938	Boron-free	3.65	7.30	10.95
Leaves	May 29, 1940	Boron-free	17.95	27.50	45.45
Trunk	May 29, 1940	Boron-free	5.95	9.63	15.58
Roots	May 29, 1940	Boron-free	13.83	15.42	29.25
Leaves	November 29, 1938	Boron (Control)	112.35	50.63	162.98
		Not Excessively High Boron in the Field			
Leaves	December 5, 1938	Riverside	37.83	60.04	97.87
Leaves	July 9, 1931	Riverside	21.60	46.88	68.48
Leaves	December 5, 1938	Riverside	85.13	60.07	145.20
Leaves	September 25, 1931	Moreno	54.35	61.88	116.23
Leaves	September 25, 1931	Moreno	58.75	70.57	129.32
Leaf Blades	June 26, 1943	Riverside	20.49	39.70*	60.19
Leaf Stalks	June 26, 1943	Riverside	3.97	16.80	20.77
Trunk Bark:					
Six foot level	January 9, 1929	Riverside	8.34	18.13	26.47
Four foot level	January 9, 1929	Riverside	6.75	18.20	24.95
Two foot level	January 9, 1929	Riverside	5.25	18.47	23.72
Six inch level	January 9, 1929	Riverside	5.09	16.86	21.95
Trunk Bark: First foot above bud union	June 22, 1933	Manure Plot, Moreno	6.75	19.05	25.80
	June 27, 1933	Ammonium Sulfate, and Pruning, Moreno	3.98	11.88	15.86
Root Bark (Black Walnut)	June 27, 1933	Riverside	8.38	21.10	29.48
		Excessively High Boron in the Field			
Leaves	September 22, 1942	Moorpark	329.75	186.25	516.00
Leaves	June 29, 1942	Sespe	200.50	101.90†	302.40
Leaf blades	June 26, 1943	Oxnard	109.38	76.80‡	186.18
Leaf blades	June 20, 1942	Oxnard	187.50	102.30	289.80

0.1 N HCl when used instead of distilled water gave the values: 17.72*, 36.20†, and 32.55‡.

Walnut seedlings were grown in solution cultures in some of which boron was omitted. In these boron-deficient cultures the mature leaflets were curled and brittle, with curled areas between the veins as shown in Fig. 1 C. The rachis (leaf stalk) and the midribs of the leaflet may show splitting (Fig. 1 D). When the boron deficiency is extreme, the meristematic tissues at the terminus of the shoot die (14) and the twig dies back together with any new growth present at the tip as shown in Fig. 1 E.

Table VII shows the reduced boron content in the walnut leaves when boron is omitted from the culture solution. In healthy leaves in the field, the leaf stalks (June 26, 1943) contained much less boron than the leaf blades. The bark of a large walnut tree of about 6 inches in diameter was tested at various distances above the soil. The water-soluble and total boron content increased slightly as the distance above the soil increased. The boron content in the trunk bark just above the bud union was greater in the tree in the manure-treated plot than in the bark of the tree in the ammonium sulfate-treated plot. Tenth normal acid, when used as the solvent instead of distilled water, brought about a greatly increased solubility of the boron in the dry matter of the leaves and leaf blades. The boron content of walnut leaves was greatly increased when the leaves were obtained from high boron areas in the field (8, 10, 13), both the water-soluble and insoluble fractions being increased.

Summary

Much of the boron in the dry matter of almond leaves is water insoluble. Large concentrations of water-soluble boron may occur in the husks of almond fruits. Even the shells and kernels may contain considerable boron.

Seedling olive plants made fair growth for some time in Pyrex glass cylinders without the addition of boron to the culture solution. In other glass containers or in aluminum kettles the lack of boron was soon evident. Boron deficiency brought about the dwarfing of new leaves and the pale color of the entire leaf blade of leaves progressively further from the shoot tip. The terminal portion of twigs died and protuberances and necrotic tissue appeared in the living portions farther back. Large reductions in the concentration of calcium supplied in the culture solution brought about the progressive yellowing (chlorosis) of the leaf blade beginning at the tip and progressively affected the leaves farther back from the shoot tip. Olive leaves from boron-deficient areas near Oroville were not only low in boron but were also low in their calcium content, which fact suggests a calcium-boron relationship. The boron content of the pulp of the Oroville fruit was very low when compared with that in fruits obtained elsewhere as noted. In culture solutions the roots were dark brown, dwarfed and disintegrating in plants receiving no boron.

Olive leaves from adjoining orchards that were not fertilized or were fertilized respectively, contained very low percentages of total nitrogen in the dry matter. Leaves of trees of the Manzanillo variety

contained higher percentages of reducing sugars and of total (calculated as reducing) sugars in the dry matter than comparable leaves of trees of the Mission variety.

Much of the boron in the dry matter of walnut husks is water insoluble. The different ages of the fruits in the several varieties result from differences in their times of flowering and maturity and affects the accumulation of boron in the fruits. Boron occurs even in the shells of walnut fruits. The water-soluble boron in the dry matter of walnut husks increased until about July 19th and then decreased.

The leaves of boron-deficient walnut seedlings were curled and brittle and with prominent veins, some of which in addition to the rachis (leaf stalk) showed splitting of the cortical tissues. The twigs died back and the roots were dark brown, dwarfed and disintegrating.

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Boron Content of Olive Leaves

By CARL J. HANSEN, *University of California, Davis, Calif.*

SCOTT, Thomas and Thomas (1) described in 1943 a disease of the olive which they cured by treatment with borax or boric acid. Leaf samples were taken from their plots and others with the object of further verifying by chemical analyses the results they obtained by observing tree response. It was also thought that once the concentration of boron in normal and deficient leaves was established, leaf analyses could be used as an aid in diagnosing the trouble, especially in those borderline cases that do not show severe dieback of shoots and chlorotic and necrotic leaf tips.

Observations of tree condition and the 69 olive leaf analyses which form the basis for the following discussion were made during the period 1941 to 1944. The boron content of leaves from normal and deficient trees is given in Table I. All analyses were made by the electrometric titration method described by Wilcox (2). Saturated calomel and glass were used for electrodes.

TABLE I—THE BORON CONTENT OF MISSION OLIVE LEAVES. WYANDOTTE DISTRICT, BUTTE COUNTY

Orchard	Tree	Condition of Tree	Boron in Dry Matter; Parts per Million
		Samples Collected December 31, 1941	
1	4	Severe deficiency symptoms, untreated part of tree	12
1	4	Branch now normal. Boric acid inserted in one hole in the branch in Feb, 1941	19
2	52	Severe deficiency symptoms; untreated part of tree	8
2	52	Branch now normal. Boric acid inserted in one hole in the branch in Feb, 1941	20
1	51	Severe deficiency symptoms	8
1	50	One of the better trees in the orchard. Trees of this type respond to boron but typical symptoms are mild or absent	14
2	50	Severe deficiency symptoms	9
2	51	One of the better trees in the orchard. Trees of this type respond to boron but typical symptoms are mild or absent	14

The boron content of leaves from trees showing severe deficiency symptoms usually fall within the range of 8 to 12 parts per million shown in Table I. However, concentrations as low as 7 p.p.m. and as high as 13 p.p.m. were found in leaves collected from severely affected trees in 1942.

Most normal leaves contain 19 to 33 p.p.m. boron. Typical analyses of leaves from normal trees in five California districts are as follows: Paradise district of Butte Co., 19, 20 and 20 p.p.m.; Solano Co., 22, 26, 29 and 33 p.p.m.; Tehama Co., 23 and 25 p.p.m.; Tulare Co., 29 and 29 p.p.m.; Yolo Co., 22, 23, 28 and 30 p.p.m.

Trees with leaves containing 14 to 15 p.p.m. have responded to applications of boron but typical deficiency symptoms are mild or absent. The remaining range of 16 to 18 p.p.m. is not clearly defined; the trees may or may not respond.

The experimental injection of dry boric acid into branches was effective in providing boron for the trees (Table I). Commercially

this has been achieved by applying borax to the soil at the rate of 1 pound per tree or approximately 50 pounds per acre. The leaves of trees that had been cured by soil applications of 13 ounces to 1 pound per tree contained from 20 to 34 p.p.m. boron.

The majority of the analyses were made on leaves of the Mission variety but preliminary evidence indicates that the conclusions drawn may be applied to other common varieties with reasonable accuracy.

In the spring of 1941 various kinds of fruit plants were placed in soil in cans (9½ inches in diameter and 11 inches deep) and irrigated with water containing the following amounts of boron: Tap water (.5 p.p.m.), 2 p.p.m., 3 p.p.m., 5 p.p.m. and 10 p.p.m. The purpose of this trial was to find the relative tolerance of fruit plants to excess boron and to determine the visible symptoms, if any. After two seasons the olive trees were normal except where the 10 p.p.m. irrigation water was used. At this concentration approximately 10 per cent of the leaves had fallen and another 10 per cent had necrotic leaf tips. It is interesting to note that boron deficient leaves also have necrotic tips, but in the case of the deficient leaves there is an intermediate golden yellow area between the brown scorched tips and the green uninjured area which is not present in the case of injury from excess boron. These trials showed the olive to be considerably more resistant to excess boron than such fruits as peach, apple, plum and apricot. For example, Elberta peach and Gravenstein apple trees were killed by both the 5 and 10 p.p.m. concentrations. In addition, the peach trees were severely injured by the 2 and 3 p.p.m. concentrations and the apple showed some injury at the 3 p.p.m. concentration. Apparently the olive is semitolerant to excess boron; therefore, it is not likely that the recommended soil applications of borax will result in injury. Eaton (3) also placed the olive in the semitolerant group. Plants such as the olive that are not easily injured by excess boron do not accumulate much boron in the leaves, while sensitive plants such as blackberry, fig and grape build up rather high concentrations. Table II contains leaf analyses of the olive trees discussed above, together with leaf analyses of three sensitive species of plants grown under comparable conditions.

The grape, fig and blackberry were normal only in the cans irrigated with tap water. All the higher concentrations resulted in leaf scorch varying from moderate at the 2 p.p.m. concentration to very

TABLE II—COMPARISON OF THE BORON CONTENT OF OLIVE LEAVES WITH THE BORON CONTENT OF THE LEAVES OF PLANTS MORE SENSITIVE TO EXCESS BORON

Irrigation Water	Boron in Dry Matter (P p m)			
	Mission Olive	Thompson Grape	Mission Fig	Young Blackberry
Tap water (0.5 p p m boron)	45	155	245	243
2 p p m boron	78	754	682	851
3 p p m boron	96	1,129	796	1,022
5 p p m boron	180	2,084	954	1,621
10 p p m boron	268	1,870	1,359	2,388

severe at the 10 p.p.m. concentration. As previously indicated, the olive was injured only at the 10 p.p.m. concentration.

Summary

Olive leaves from a limited number of boron deficient and normal trees were analyzed for boron and the approximate leaf concentrations associated with normal growth were indicated. It is suggested that leaf analyses may be of assistance in diagnosing boron deficiency in the olive, especially in those borderline cases where typical symptoms are mild or absent. Evidence is presented to show that the olive is semitolerant to excess boron so the recommended soil applications should not prove harmful.

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Fruit Set in the Sweet Orange in Relation to Flowering Habit

By PHILIP C. REECE, *U. S. Department of Agriculture, Orlando, Fla.*

EXTENSION of branch development, including flower production of the sweet orange, takes place by growth from axillary buds, since in a true morphological sense there are no terminal buds in citrus. At flowering time, some of these axillary buds, present on a flush of growth of the preceding season, elongate into leafy shoots without flowers, while others may give rise to very short laterals bearing one or more flowers but without leaves. These two types of growth represent the extreme of purely vegetative and purely floral development.

FIG. 1. New shoots from axillary buds bearing both leaves and flowers, in this study termed "leafy" inflorescences. Flowers appear singly in leaf axils on "new wood."

Between these extremes, some buds develop into shoots bearing both leaves and flowers, the flowers appearing singly in the axils of the leaves on the new growth. This condition is commonly known to growers as bloom on the "new wood" (Fig. 1). When the growth from the buds is purely floral, that is, consisting of flowers unaccompanied by new leaves, the bloom is said to be on the "old wood" (Fig. 2). Usually both types of bloom are present, and frequently they ap-

FIG. 2. Purely floral growth from axillary buds, consisting of flowers unaccompanied by new leaves. Bloom of this type is commonly said to be on "old wood."

pear on the same branch. However, the proportion of "old wood" to "new wood" bloom varies greatly, and a predominance of one or the other in general characterizes the type of bloom of a tree. The term "old wood" bloom is, of course, inaccurate because in all cases the flowers are on new wood, although this fact is frequently not apparent because the axes on which the flowers are borne in this instance are very short and leafless.

In this paper the term "inflorescence" will be used in a very broad sense, to cover any type of floral development that may appear from a given axillary bud upon a twig of the preceding season's growth. The inflorescence will be referred to as "leafless" if the growth consists of one or more flowers but without leaves ("old wood" bloom), and "leafy" if the flowers are axillary on new leafy shoots ("new wood" bloom). Intergrading types exist in which the development is chiefly floral but with only one or two leaves present upon the general stalk along which the flowers are disposed. These intergrading forms have arbitrarily been classed as "leafy" inflorescences. While grower opinion concerning the relative merits of the two types of bloom is divided, it is most commonly thought that flowers on the "old wood" are stronger and more likely to set a good fruit crop. Contrary to this general belief, evidence is herein presented which shows that bloom on "new wood" is far superior for fruit set in the case of the sweet orange.

Methods

The trees used in this study are on rough lemon root in the Isleworth grove (in Orange County, Fla.) of the Chase Investment Company, to whom we are indebted for their cooperation. This grove is maintained in good condition and produced satisfactory crops in the seasons of this experiment. In the spring of 1943, 100 branches of the Pineapple variety and 340 of the Hamlin were tagged, and the type of inflorescence and the number of flowers produced from each axillary bud were recorded at flowering time. Subsequent counts were made periodically during the growing season to determine the percentage of fruit set on each inflorescence. In 1944 the study was extended to include Valencia, of which variety 400 branches were used. Thus the data which follow cover the flowering and fruiting behavior in two separate years. The similarity of the results in the two seasons, even though with different varieties, will be apparent.

Results

In Table I the average number of flowers per inflorescence produced by the leafy and leafless types is presented. The data disclose that in each variety studied the leafy inflorescences bore the larger number of flowers. Leafless inflorescences of the Pineapple variety

TABLE I—Number of Flowers per Inflorescence

Inflorescence	Varieties of Sweet Oranges					
	Pineapple		Hamlin		Valencia	
	Type of Inflrs.		Type of Inflrs.		Type of Inflrs.	
	Leafy	Leafless	Leafy	Leafless	Leafy	Leafless
Number of inflorescences counted	217.0	369.0	505.0	659.0	821.0	959.0
Number of flowers per inflorescence	4.8	3.6	4.5	2.8	4.4	2.8

bore an average of 3.6 flowers, while leafy inflorescences bore 4.8 flowers, or 1.3 times as many as the former. In the Hamlin and Valencia varieties the leafy type bore 1.6 times as many flowers.

The superiority of the leafy over the leafless inflorescences in fruit set is apparent in Table II, which shows the percentage of the two types that still carried fruit when the final counts were made in the fall. With all three varieties and regardless of whether the floral development was borne on the first or second growth flush of the previous season, the percentages of leafy inflorescences that bore fruit were much higher than in the case of the leafless.

TABLE II—PERCENTAGE OF INFLORESCENCES THAT BORE FRUIT

Inflorescence	Varieties of Sweet Orange					
	Pineapple		Hamlin		Valencia	
	Type of Inflrs.		Type of Inflrs.		Type of Inflrs.	
	Leafy	Leafless	Leafy	Leafless	Leafy	Leafless
	First Flush					
Number of Inflorescences	97.0	150.0	354.0	535.0	568.0	543.0
Percentage fruiting	33.0	9.3	16.9	6.9	33.1	9.2
	Second Flush					
Number of Inflorescences	120.0	219.0	151.0	124.0	253.0	416.0
Percentage fruiting	43 3	12.8	17.9	4.0	35.3	10.8
	All Flushes					
Number of Inflorescences	217.0	369.0	505.0	659.0	821.0	959.0
Percentage fruiting	38.7	11.4	17.2	6.4	33.0	9.9

Data are presented in Table III on the percentage of individual flowers that fruited on the two types of inflorescences. The percentage of fruit set is shown 1 month after flowering, before all drop was completed, and finally in the fall. After that time any further drop could be attributed to other factors not related to the problem under discussion. When the final counts were made, 9.9 per cent of the Pineapple orange flowers of leafy inflorescences were producing fruit, in contrast with only 3.4 per cent of the leafless type. Thus a flower on a leafy inflorescence had 2.9 times the probability of maturing a fruit as a flower of a leafless inflorescence. The percentages of flowers to bear fruit in the Hamlins were 4.4 on the leafy and 2.3 on the leafless, or flowers of the first type did 1.9 times as well. For Valencias, the set on leafy inflorescences was 8.1 per cent as compared with 3.5 per cent, or 2.3 times the set on leafless inflorescences.

Not only did a greater percentage of the flowers on leafy inflorescences produce fruit, but this type of inflorescence actually carried a greater number of flowers, as is shown in Table I. Leafy inflorescences of the Pineapple orange, for example, had on the average 1.3 times the number of flowers produced by the leafless type, and each flower had 2.9 times the chance of bearing a fruit. Thus the total advantage for fruit set of purely leafy bloom over purely leafless

TABLE III—PERCENTAGE OF INDIVIDUAL FLOWERS THAT PRODUCED FRUIT

Flowers	Varieties of Sweet Oranges					
	Pineapple		Hamlin		Valencia	
	Type of Inflrs		Type of Inflrs		Type of Inflrs	
	Leafy	Leafless	Leafy	Leafless	Leafy	Leafless
First Flush						
Number of flowers	484	517	1,505	1,455	2,389	1,568
Percentage fruiting						
Apr 26 count	40.9	16.1	31.0	18.9	8.8	3.4
Oct 21 count	8.7	2.7	4.7	2.5	8.4*	3.2
Second Flush						
Number of flowers	556	818	769	405	1,171	1,117
Percentage fruiting						
Apr 26 count	28.1	12.5	31.3	18.0	9.0	7.4
Oct 21 count	11.0	3.8	3.8	1.2	7.4*	4.0
All Flushes						
Number of flowers	1,040	1,335	2,274	1,860	3,560	2,685
Percentage fruiting						
Apr 26 count	34.0	13.9	31.1	18.7	8.8	5.4
Oct 21 count	9.9	3.4	4.4	2.3	8.1*	3.5

*Sep 1.

bloom was 2.9 multiplied by 1.3, or 3.8 times as much fruit. Similarly, in the Hamlin and Valencia used in this study the advantage of the bloom on leafy inflorescences was 3.0 and 3.7 times, respectively.

Although leafy inflorescences consistently produce a higher percentage of the total crop than leafless inflorescences, apical dominance is also a factor. Regardless of whether the inflorescence is leafless or leafy, the per cent of the total fruit set by each type is greater with increased proximity of the inflorescence to the end of the twig. Data presented in Table IV show that inflorescences arising at the first node, counting from the tip, produced 22.5 per cent of the total crop in the Pineapple variety, 23 per cent in the Hamlin, and 35.1 per cent in Valencia, and that the fruit set decreased at each succeeding node until at the seventh node the inflorescences produced only 4.9 per cent

TABLE IV—PERCENTAGE OF TOTAL CROP CARRIED BY INFLORESCENCES AT VARIOUS NODES

Sweet Orange Varieties	Type of Inflorescences	Position of Inflorescences by Nodes, Counting From the Apex							
		1	2	3	4	5	6	7	All others, combined
Pineapple	Leafy	14.8	13.4	9.9	4.9	6.3	6.3	4.2	
	Leafless	7.7	2.1	2.1	4.9	5.6	2.8	0.7	
	Combined	22.5	15.5	12.0	9.8	11.9	9.1	4.9	14.3
Hamlin	Leafy	13.8	13.8	9.2	5.9	7.9	5.1	3.9	
	Leafless	9.2	4.6	1.3	3.9	4.6	2.1	1.4	
	Combined	23.0	18.4	10.5	9.8	12.5	7.2	5.3	13.3
Valencia	Leafy	29.4	18.6	10.2	8.1	2.7	3.5	1.9	
	Leafless	5.7	5.9	6.5	3.0	1.6	0.8	0.8	
	Combined	35.1	24.5	16.7	11.1	4.3	4.3	2.7	1.3

in Pineapple, 5.3 per cent in Hamlin, and 2.7 per cent in Valencia. Nevertheless, the flowers borne on leafy inflorescences retained their pronounced setting superiority over the leafless type, regardless of apical dominance.

It remains to be shown what factors influence the type of bloom produced by an orange tree and what specific cultural practices can best be employed to shift the type of bloom in the direction of more numerous leafy inflorescences. Even in groves in which there is a relatively high percentage of leafy bloom, such as the one used in this study, it appears that the crop could be considerably increased if only a slight shift of leafless inflorescences to the leafy type could be brought about. In groves in which the bloom is almost all of the leafless type a shift to a predominantly leafy type would result in a very large increase in fruit production.

It should be emphasized that the results of the above study apply only to the sweet orange. A similar study is now in progress on the flowering and fruiting habit of the grapefruit and tangerine. These may or may not behave like the sweet orange.

Blossom Structure and Setting of Delicious and Other Apple Varieties[1]

By R. H. Roberts, *University of Wisconsin, Madison, Wisc.*

Unsatisfactory crops of Delicious are a common experience for growers of this variety in the upper Mississippi Valley. While it is not extensively planted, it is generally grown and when topworked to increase winter hardiness, the red sports yield desirable fruits when a set can be secured.

Pollination experiments were conducted in 1943, being designed to secure information on the setting of Delicious. Emasculating was done by slipping the calyx. No fruits developed from Delicious blossoms emasculated by this method. The common varieties Dudley, Jonathan, McIntosh, Snow (Fameuse), Wealthy and Wolf River were all self unfruitful but interfertile. Red Rome was self fruitful.

In 1944, cross pollination by insects was prevented by either (a) removing the petals, (b) removing the petals and anthers, (c) covering branches with paper bags, or (d) with cheesecloth bags. The blossom clusters were thinned to two to a spur. No Delicious fruits developed from self pollination. Sets ranging from 37.5 per cent to 84.1 per cent after the first drop were secured with pollen of Duchess, Cortland, Jonathan, McIntosh, McMahon, Northwestern Greening and Red Rome. The Wealthy pollen used gave less set. The sample was apparently poor as it was also less effective on other varieties. No Delicious fruits set from blossoms having the petals removed but left exposed to wind and to insect visitation. Some fruits developed from pollinated blossoms which had been previously emasculated by careful slipping of the calyces. Apparently Delicious may not be much more difficult to set than several other varieties but its blossoms are injured more by removing the calyces. At any rate, the kind of pollen available was obviously not a principal cause for the failure of fruit to set this season in Wisconsin.

It is believed that an important contributing factor to the frequent poor setting of Delicious has been found. It was noted that the structure of the Delicious blossom is such as to permit honeybees to extract the nectar without pollinating the blossoms (Fig. 1). In only about 20 per cent of the visits did this insect crawl over the anthers and stigmas.

The pistils of Delicious are so short that the bees which collect pollen rather than nectar do not always touch the stigmas (Fig. 2).

Bumblebees "pollinate" the blossoms at every visit as they always crawl over the tops of the blossoms. Orchards of Delicious having a good bumblebee population set well this year.

Nutritional factors apparently enter largely into the first drop of Delicious. The fact that orchards with bumblebees set well is clear evidence that the first drop is not entirely a matter of nutrition. Further evidence that pollination is involved in the "blossom drop" is

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FIG. 1. Blossoms of Delicious (left), Wealthy (center) and Transparent (right). The upright position of the filaments and spreading petals of Delicious permit honeybees and solitary bees to extract nectar without contacting the anthers or pistils in 80 per cent of their visits. The spreading filaments of varieties as Wealthy and Transparent cause the bees to crawl over the pistils and enter the blossom from the center.

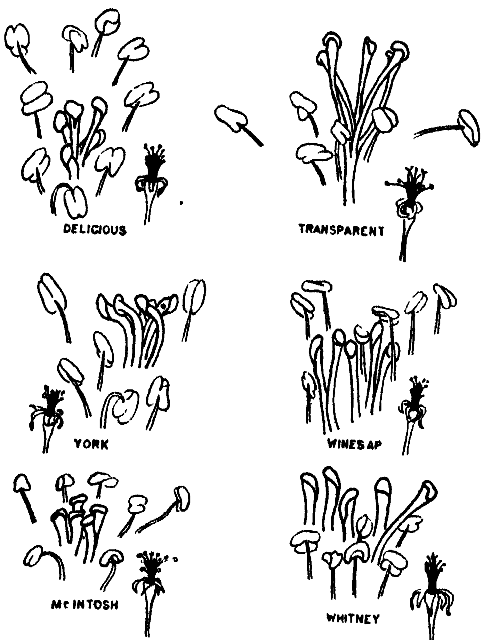

FIG. 2. Diagrams of anther and style positions of some varieties of apples. Delicious represents a "poor pollinator"; Transparent a good one. McIntosh is medium good. Whitney is good because strongly cupped petals force bee visitation over the pistils.

contributed by observations on the presence of pollen tubes in the vicinity of the ovules. Drop blossoms without tubes amounted to 31.3 per cent for Delicious and 31.8 for Wealthy. With the technique used of dissecting free hand sections under an aqueous solution of Lacmoide (resorcin blue), tubes were found in the carpel cavities of 98.2 per cent of the set fruits of Delicious and 91.2 per cent of Wealthy. Samples from Delicious trees with bumblebees, when the initial set was 67.8 per cent of total blossoms, showed 96.6 per cent of the dropped fruits had pollen tubes. In this same orchard, the set of Wealthy was 83.8 per cent, and 85.0 per cent of drop blossoms had tubes. In a Delicious

orchard with a 9.8 per cent initial set, tubes were found in 25.5 per cent of the early drops.

No studies were made of fertilization conditions other than the observation that the ovules enlarge following fertilization and fail to do so in unpollinated blossoms which drop. Growing ovules are found in pollinated blossoms which drop from nutritional causes.

Observations of the blossoms of other varieties disclosed a marked relation between the way that honeybees extract nectar from them and the well known fruit-setting reputations of the varieties (Fig. 3). Poorer setting kinds have blossoms with a structure like Delicious and those which habitually set heavily have blossom characters which cause the bees to crawl over the pistils.

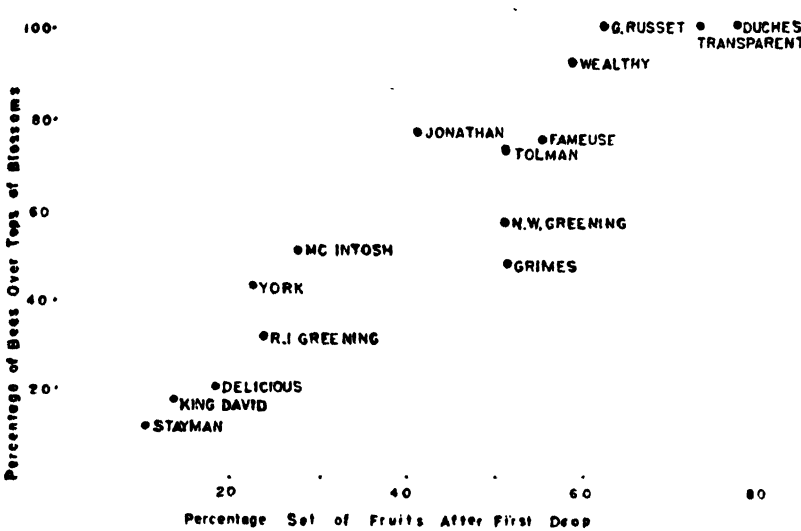

FIG. 3. The relation of bee visits over the tops of the blossoms to fruit set after the first drop.

The distance from a pollen source at which honeybees were effective pollinators for Delicious is indicated by the following record from an orchard with no evident bumblebees, and only a moderate honeybee population. There was an initial set of 220.0 blossoms and a final set of 50.0 fruits per 100 blossoming spurs on the sides of the trees next to another variety. The far sides of the same trees had 90.0 and 37.3 fruits per 100 blossoming spurs. Trees in the second row from the pollen source had fewer fruits, the counts being 81.0 and 16.7 per 100 blossoming spurs. This is too few for a good crop. For a good commercial crop, 30 to 40 fruits per 100 blossoming spurs when 70 to 80 per cent of the spurs blossom are needed. The best crops come from trees with fewer blossoms and better percentage sets.

This year a good initial set of Delicious resulted from a good popu-

lation of bumblebees, a very nearby pollen source, or very high honeybee populations. When these conditions did not prevail, poor sets resulted as Delicious blossoms were not pollinated by honeybees in more than 20 to 25 per cent of the visits being made, even if the bees would be carrying foreign pollen. A consideration of this fact in future observations should help in determining more accurately the role of nutrition in fruit setting of Delicious and in better evaluating the effect of such practices as pruning and fertilizer applications upon set.

The Spontaneous Origin of Polyploid Apples[1]

By JOHN EINSET, *New York State Agricultural Experiment Station, Geneva, N. Y.*

IN 1937 Johansson (4) reported the occurrence of a tetraploid apple seedling with 68 chromosomes from a cross of the triploid variety Belle de Boskoop as seed parent, with the diploid variety Filippa as pollen parent. The same year Nilsson-Ehle (5) planted approximately 80,000 seeds at Alnarp from fruits of the triploid varieties Belle de Boskoop and Blenheim. Open pollination prevailed and, according to the author, probably mostly pollen of diploid varieties functioned. Chromosome number determinations were made in selected, vigorous seedlings and four tetraploid plants with 68 chromosomes were reported in the Belle de Boskoop progenies. A later paper by Aschan (1) indicates that a total of seven tetraploid seedlings was found in the offspring of triploid apple varieties grown at Alnarp. In 1944 the writer (2) reported the spontaneous occurrence of a tetraploid and two triploid apple seedlings in progenies of diploid parents. Since that time chromosome numbers have been determined in a larger number of seedlings from diploid as well as triploid parents.

Chromosome number determinations were made in root-tips of 1740 seedlings with diploid parents (Table I). Four triploid seedlings and three tetraploids were found. The triploids originated presumably

TABLE I—THE OCCURRENCE OF TRIPLOID AND TETRAPLOID SEEDLINGS IN PROGENIES OF DIPLOID PARENTS

Breeding Record No.	Cross*	Triploids (51 Chromosomes)	Tetraploids (68 Chromosomes)	N**
42301	Delicious × Bedford	2	–	134
42303	Macoun × Jonathan	–	1	85
43007	Ogden × Transparent de Croncels	–	1	10
43012	Golden Delicious × Bedford	–	1	172
43013	Golden Delicious × Jonathan	1	–	165
43021	Red Spy × Golden Delicious	1	–	200
	Other crosses	–	–	974
	Total	4	3	1,740

*The seed parent stands first in each case.
**N equals the number of individuals in the population.

through the functioning of an unreduced egg or possibly a pollen grain. Whether the tetraploids arose through the chance union of two unreduced gametes or through somatic doubling of the zygote cannot be determined. The low probability of chance union of two unreduced gametes makes the latter supposition more probable. Also the relatively frequent occurrence of single cells or sectors with the doubled chromosome number in the root tips indicates that such somatic doubling does occur not infrequently.

A total of 532 seedlings grown from open pollinated seed of triploid apple varieties was examined as to chromosome number (Table II). Ten tetraploids with 68 chromosomes were found. Another seedling

[1]Journal Paper No. 635 of the New York State Agricultural Experiment Station.

TABLE II—THE OCCURRENCE OF TETRAPLOID SEEDLINGS IN PROGENIES OF OPEN POLLINATED TRIPLOID APPLES

Breeding Record No.	Seed Parent	Tetraploids (68 Chromosomes)	N*
43042	Fallawater	2	55
43046	Graue Herbst Reinette	4	24
43063	Red Gravenstein	5**	198
	Other triploid parents	–	255
	Total	11	532

*N equals the number of individuals in the population.
**One seedling had 71 chromosomes instead of the balanced tetraploid number of 68.

had 71 chromosomes. It is likely that these seedlings arose as the result of the functioning of unreduced eggs with three sets of chromosomes fertilized by pollen with one set of chromosomes from diploid varieties. The 71 chromosome plant is presumably the result of the union of an unreduced egg (51 chromosomes) plus a pollen grain from a triploid variety which carried 20 chromosomes. That this is the probable explanation of the origin of these seedlings is borne out by the chromosome numbers of their sister plants (Table III). The

TABLE III—CHROMOSOME NUMBERS OF SEEDLINGS OF OPEN-POLLINATED TRIPLOID SORTS

Chromosome Number	Number of Seedlings	Chromosome Number	Number of Seedlings
17 (N)	2	52	–
		53	1
34(2N)	6	54	1
35	3	55	1
36	9	56	–
37	20	57	–
38	30	58	1
39	32	59	–
40	49	60	2
41	31	61	1
42	39	62	–
43	26	63	–
44	19	64	–
45	15	65	–
46	13	66	–
47	6	67	.
48	4	68(4N)	10
49	1		
50	2	71	1
51(3N)	4	Total....	329

bulk of these lie in the range 34 through 51 which would be expected if mostly pollen from diploid varieties functioned; the chromosome numbers of the egg cells varying from 17 through 34 and the pollen contributing 17 chromosomes. If pollen from triploids functioned, the chromosome numbers of the seedlings should theoretically range from 34 through 68. In the 329 seedlings where exact chromosome number determinations were made in the root tips, very few plants were found in the 52–68 range. No plants were found in the 62–67 range. This indicates that the 68 chromosome seedlings were not formed through chance union of high chromosome gametes but originated through an entirely different phenomenon, namely the functioning of unreduced egg cells.

A total of 14 tetraploid plants has been found to date. Twelve of these plants are still alive, two having been lost in the nursery row. It is planned to bring these tetraploids into fruiting and through crossing with selected diploid varieties to produce triploids in numbers sufficient to determine whether triploid apples are inherently superior to diploid sorts in late keeping quality (3) and in other desirable characteristics.

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Apple Thinning with Caustic Sprays Applied During the Blossom Period

By L. P. Batjer, H. H. Moon, and C. F. Kinman, *U. S. Department of Agriculture, Beltsville, Md.*

The feasibility of either completely or partially reducing the set of apples with caustic sprays applied during the bloom period has been studied by a number of investigators since the original investigations of Auchter and Roberts (1) in 1933. Of a great variety of materials tested for this purpose the dinitro-cresol compounds (5, 4, 2) have generally proved the most promising. Results with some varieties in several places have proved sufficiently consistent that rather extensive commercial use of these sprays is being made as a substitute for, or a supplement to, hand thinning. In some instances, however, results have been so variable, depending upon such factors as time of spray application, tree vigor, weather conditions and possibly others, as to raise a question regarding the practicability of these sprays under many conditions. The experiments herein reported were particularly designed to more properly evaluate the commercial feasibility of blossom sprays for fruit thinning under conditions prevailing in the Cumberland-Shenandoah fruit region.[1]

Methods

These experiments were conducted in 1943 and 1944 on the varieties York Imperial, Yellow Transparent, Grimes Golden, and Golden Delicious, in orchards located in the vicinity of Martinsburg, West Virginia, and Hancock, Maryland. The trees used varied considerably in age and vigor, but all carried a heavy bloom and in most cases were decidedly alternate in bearing habit. The toxicant used in most of the spray treatments was the sodium salt of dinitro-cresol (Elgetol) in dilute solutions. Some of the treatments in 1944 included dinitro-ortho-cresol (DN Wettable No. 2) and the amine salt of dintro-ortho-cresol (DN No. 111).

The sprays were thoroughly applied with 500 pounds pressure, using a 6-nozzle broom (with No. 3 discs) from the ground and a single-nozzle gun (No. 12 disc) operated from the top of the spray machine. In all cases single spray treatments were applied either on the first day of full bloom (beginning of petal fall) or from 32 to 72 hours following full bloom. Unless otherwise stated, each treatment consisted of eight to 10 trees randomized throughout the experimental blocks. Fruit set records were obtained by counting from 1200 to 2000 blossom clusters on 4 typical limbs in each tree. Fruit set on these limbs was determined after the June drop. Careful estimates were made of the production capacity of each tree in most of the experiments. The "per cent of a capacity crop" shown in Tables II and IV is therefore the tree yield divided by the tree capacity. It

[1]The authors wish to acknowledge the helpful aid of Mr. Edwin Gould, of the West Virginia Agricultural Experiment Station, whose cooperation made these experiments possible.

was felt that this method of expressing yield gave a fairly accurate picture of the effect of treatment, since it tended to eliminate irregularities that resulted from differences in tree size. In order to obtain the effect of 1943 treatments on biennial bearing, estimates were made in 1944 of bloom and yield in several of the experimental blocks.

Weather Conditions of 1943 and 1944

The period of apple bloom in 1943 in the area where these studies were conducted was characterized by unusually cool, windy weather, which caused a rather slow, prolonged development of blossoms. The weather conditions prevailing during the 1944 blossoming season, however, were considered almost ideal for pollination and fruit set. The temperatures for the two years are shown in Table I.

TABLE I—Temperatures During 1943 and 1944 Bloom Seasons at Kearneysville, W. Va.

Month and Day	1943			1944		
	Min.	Max.	Mean[1]	Min.	Max.	Mean[1]
	(Degrees F)	(Degrees F)	(Degrees F)	(Degrees F)	(Degrees F)	(Degrees F)
Apr 27	43	69	57	—	—	—
Apr 28	44	72	62	—	—	—
Apr 29	36	62	51	—	—	—
Apr 30	52	76	58	40	76	59
May 1	40	54	47	48	78	65
May 2	34	61	49	61	80	69
May 3	51	76	60	52	82	69
May 4	48	60	52	56	84	72
May 5	36	68	54	58	82	72
May 6	42	90	65	62	67	64
Average	42.6	68.8	55.5	53.9	78 4	67.1

[1]Mean was calculated by averaging the temperature at 2-hour intervals throughout the 24-hour period.

1943 Results

As compared with unsprayed trees, all Elgetol spray treatments on York Imperial and Grimes Golden (Table II), as well as Yellow Transparent (Table III), resulted in significant reduction of fruit set and yield and an increase in fruit size. It may be further noted from Table II and Table III that no statistically significant difference was obtained in fruit set, size, or yield in relation to either time of application or spray concentration, although the data generally show a numerically smaller fruit set with the stronger sprays. With the York Imperial variety (Table II) the most satisfactory results of the spray from the standpoint of increasing fruit size with the least loss in volume of fruit was obtained in the Green Lane Orchard. These trees, 30 to 35 years old, were generally in good vigor and had received rather liberal yearly applications of nitrogenous fertilizers. In this test the fruits from the sprayed trees averaged nearly ¼ inch larger in diameter than fruits from unsprayed trees, with average yields of 16.5 and 20.0 bushels for the sprayed and unsprayed trees, respectively. Considerable variation in set reduction and yield occured among the treated trees; nevertheless, all but one of these trees

TABLE II—EFFECT OF ELGETOL SPRAY APPLIED DURING BLOSSOMING PERIOD ON SET, SIZE, AND YIELD OF YORK IMPERIAL AND GRIMES GOLDEN APPLES. 1943

Number of Trees in Treatment	Spray Concentration (Per Cent)	Date Applied	Stage of Bloom	Number Fruits per 100 Blossoming Spurs	Yield (Bushels)	Per Cent of Capacity Crop	Number of Fruits Per Bushel	1944 Estimates: Bloom (Per Cent)	1944 Estimates: Yield (Bushels)
York Imperial, Green Lane Orchard									
41	Check	—	—	—	20.0	91	214	0.2	0.3
33	0.15	5/6; 9 a.m.	—	—	16.5	75	162	5.0	5.7
Diff. necessary for sig. at 5 per cent point					3.2	—	14	—	—
York Imperial, Cushwa Orchard									
10	Check	—	—	26.2	17.1	100	200	2.0	1.0
10	0.15	5/4; 9 a.m.	F.B.[1]	12.6	12.6	63	140	7.0	5.6
10	0.21	5/4; 9 a.m.	F.B.	7.9	8.8	51	126	6.0	3.6
10	0.15	5/5; 5 p.m.	L.B.[2]	9.4	10.7	53	126	13.0	5.9
10	0.21	5/5; 5 p.m.	L.B.	5.6	7.9	43	142	10.0	5.5
Diff. necessary for sig. at 5 per cent point				5.6	5.2	—	22	—	—
York Imperial, Chew Orchard									
8	Check	—	—	23.0	20.7	80	—	8.0	4.0
8	0.15	5/1; 7 p.m.	F.B.	4.6	7.4	28	—	31.0	12.0
8	0.21	5/1; 7 p.m.	F.B.	4.2	5.5	22	—	25.0	14.0
8	0.15	5/4; 7 p.m.	L.B.	4.4	6.1	23	—	31.0	13.0
8	0.21	5/4; 7 p.m	L.B.	3.8	4.6	20	—	28.0	12.0
Diff. necessary for sig. at 5 per cent point				6.0	4.5	—	—	—	—
Grimes Golden, Kearneysville Station Orchard									
8	Check	—	—	25.2	18.4	—	—	—	—
8	0.15	4/29; 8 a.m.	F.B.	6.3	6.5	—	—	—	—
8	0.21	4/29; 8 a.m.	F.B.	5.1	5.8	—	—	—	—
8	0.15	5/1; 7 p.m.	L.B.	3.9	7.3	—	—	—	—
Diff. necessary for sig. at 5 per cent point				5.7	5.9	—	—	—	—

[1]Full bloom. [2]Late full bloom.

came back in 1944 with sufficient bloom for at least a partial crop, while all 29 check trees failed to fruit.

Elgetol spray treatments applied to York Imperial in the Cushwa Orchard resulted in a somewhat greater reduction in fruit yield than in the Green Lane Orchard. In the Chew Orchard, which was considerably higher in vigor than the Cushwa Orchard, these treatments resulted in a greater reduction in set and yield as compared with unsprayed trees, than in the Cushwa Orchard.

It should be pointed out that none of the check trees in the York Imperial experiments set a heavy crop for this variety. Fruit sets of around 25 per 100 blossoming spurs are ample for a full crop when the bloom is heavy, but sets of 40 to 60 fruits per 100 blossom clusters are common with this variety when conditions for fruit set are favorable.

The effect of the Elgetol treatments on Yellow Transparent in all three orchards (Table III) was to reduce fruit set significantly, a condition which in turn was associated with increase in ultimate fruit

size. In the Green Lane Orchard a set of 22 per cent on the sprayed trees, with an average yield of 4.5 bushels, was considered almost

TABLE III—EFFECT OF ELGETOL SPRAY APPLIED DURING BLOSSOMING ON SET, SIZE, AND YIELD OF YELLOW TRANSPARENT APPLES. 1943

Number of Trees in Treatment	Spray Concentration (Per Cent)	Date Applied	Stage of Bloom	Number Fruits Per 100 Blossoming Spurs	Yield (Bushels)	Per Cent of Fruits Under 2 Inches in Diameter
			Green Lane Orchard			
10	Check	—	—	72.3	7.0	76
10	0.15	5/4; 10:00 a.m.	F.B.[1]	22.4	4.5	34
Diff. necessary for sig. at 5 per cent point				23.8	2.5	—
			Cherry Run Orchard			
9	Check	—	—	59.6	—	—
9	0.15	5/1; 11:00 a.m.	F.B.	32.7	—	—
9	0.21	5/1; 11:00 a.m.	F.B.	33.9	—	—
Diff. necessary for sig. at 5 per cent point				7.1		
			Stuart Orchard			
10	Check	—	—	55.8	—	52.8
10	0.15	4/29; 5 00 a.m.	F.B.	33 7	—	29.0
10	0.21	4/29; 5:00 a.m.	F.B.	29 7	—	34.8
10	0.15	5/2; 7:30 a.m.	L.B.[2]	36.6	—	32.5
10	0.21	5/2; 7:30 a.m.	L.B.	29.5	—	31.5
Diff. necessary for sig. at 5 per cent point				8.2	—	7.9

[1]Full bloom. [2]Late full bloom.

ideal from the standpoint of fruit size. A number of sprayed trees in this orchard bloomed sufficiently for a partial crop in 1944. The spray treatments on this variety in the Cherry Run and Stuart Orchards (which were relatively lower in vigor than the Green Lane Orchard), while significantly reducing fruit set, did not bring it to the usual thinning level required for the most satisfactory results with this variety. In the Cherry Run Orchard, where about 300 trees were sprayed commercially with Elgetol, the owner supplemented the spray treatment with hand thinning, with about one-third the labor required to thin unsprayed check trees. None of the trees receiving spray treatments in the Cherry Run and Stuart Orchards blossomed in 1944.

The effect of blossom spraying with Elgetol on fruit set and yield of Grimes Golden is shown in Table II. All spray treatments resulted in marked reduction in fruit set and yield.

1944 RESULTS

The 1944 results with blossom-thinning sprays were in decided contrast to those obtained in 1943. All treatments in 1944 (Table IV) (with the exception of DN No. 111 on Grimes Golden in the Hockensmith Orchard) resulted in a significant reduction in fruit set and an increase in fruit size. The increase in fruit size seemed largely to compensate for the reduction in fruit set, since in most instances there were only slight-to-moderate decreases in the total volume of fruit per tree. In some instances the treatments actually show the

TABLE IV—EFFECT OF DINITRO-CRESOL SPRAYS APPLIED DURING THE BLOOM PERIOD ON SET, SIZE, AND YIELD OF APPLES. 1944

Number of Trees in Treatment	Spray Treatment	Date Applied	Stage of Bloom	Number Fruits Per 100 Blossoming Spurs	Yield Per Tree (Bushel)	Per Cent of Capacity Crop	Number of Fruits Per Bushel
	York Imperial Porterfield Orchard						
10	Check			15.7	22.5	73	185
10	0.20 per cent Elgetol	5/3; 5:45 p.m.	F.B.[1]	9.8	15.5	57	142
Diff. necessary for sig. 5 per cent				5.2	8.1		13
	York Imperial Hockensmith Orchard						
8	Check			58.0	26.6	94	238
8	0.20 per cent Elgetol	5/3; 2:30 p.m.	F.B.	38.6	26.1	87	184
Diff. necessary for sig. 5 per cent				8.7	3.9	—	28
	York Imperial Fairview Orchard						
10	Check			43.7	16.6	74	—
10	0.20 per cent Elgetol	5/4; 9:15 a.m.	F.B.	26.9	14.6	63	—
Diff. necessary for sig. 5 per cent				5.1	5.8	—	—
	York Imperial Jefferson Orchard						
10	Check			55.7	29.0	100	198
10	0.20 per cent Elgetol	5/3; 4:30 p.m.	F.B.	32.3	28.2	98	144
10	0.8 lb. DN No. 2 per 100 gal. water[2]	5/3; 4.30 p.m.	F.B.	30.0	26.8	95	152
Diff. necessary for sig. 5 per cent				9.0	5.9	—	17
	Grimes Golden, Pike Orchard						
9	Check			49.4	25.6	100	261
9	0.10 per cent Elgetol	5/2; 10:30 a.m.	F.B.	30.7	16.1	85	210
9	0.15 per cent Elgetol	5/2; 11:00 a.m.	F.B.	22.3	10.7	56	170
9	0.6 lb. DN No. 2 per 100 gal. water	5/2; 11:30 a.m.	F.B.	23.7	13.3	66	180
9	0.10 per cent Elgetol	5/4; 8:00 a.m.	L.B.[3]	29.8	21.3	99	198
9	0.15 per cent Elgetol	5/4; 8:30 a.m.	L.B.	33.6	18.4	92	184
Diff. necessary for sig. 5 per cent				12.5	4.9	—	34
	Grimes Golden, Hockensmith Orchard						
9	Check			50.3	21.5	70	342
9	0.10 per cent Elgetol	5/2, 8:00 a.m.	F.B.	27.7	13.9	57	257
	0.15 per cent Elgetol	5/2; 8:20 a.m.	F.B.	26.8	15.8	56	257
Diff. necessary for sig. 5 per cent				8.7	3.9	—	28
	Golden Delicious, Lingemfelter Orchard						
10	Check			54.1	24.4	100	220
10	0.13 per cent Elgetol	5/4; 2:00 p.m.	F.B.	34.0	19.7	98	170
10	0.19 per cent Elgetol	5/4; 2:20 p.m.	F.B.	28.9	18.5	89	155
10	0.13 per cent Elgetol	5/6; 8:00 a.m.	L.B.	41.4	25.2	100	178
10	0.19 per cent Elgetol	5/6; 8:20 a.m.	L.B.	38.2	23.7	100	179
10	0.5 lb. DN No. 2 per 100 gal. water	5/4; 2:40 p.m.	F.B.	28.7	19.1	92	155
5	0.5 lb. DN No. 111 per 100 gal. water[4]	5/4; 3:00 p.m.	F.B.	44.0	25.1	100	166
Diff. necessary for sig. 5 per cent				7.3	4.9	—	18

[1]Full bloom.
[2]A solution of 1.0 pound DN Wettable No. 2 in 100 gallons contains approximately the same amount of toxicant as a 0.25 per cent solution of Elgetol.
[3]Late full bloom.
[4]A solution of 1.0 pounds DN No. 111 in 100 gallons contains approximately the same amount of toxicant as a 0.13 per cent solution of Elgetol.

same crop on a "percentage of capacity crop" basis as the untreated trees. The failure of check trees in a number of the experiments to yield 100 per cent of a capacity crop was chiefly due to moisture deficiency, which reduced fruit size, and severe infestations of codling moth, which resulted in premature fruit drop.

At the present time no explanation can be offered for some of the apparent inconsistencies in the data and no attempt will be made to discuss the results of each treatment in detail. The results in 1944 were similar to those in 1943 in showing no clear-cut or consistent difference between spray concentrations within the ranges tested. It may also be seen that in the three instances where the dinitro-ortho-cresol powder (DN Wettable No. 2) was used at the same concentration of toxicant as sodium dinitro-cresylate (Elgetol), there was little essential difference in the results obtained. The amine salt of dinitro-ortho-cresol (DN No. 111) in one test on Golden Delicious resulted in appreciable fruit set reduction when used at a concentration of toxicant one-half as great as that of the DN No. 2 spray and the 0.13 per cent Elgetol spray.

Effect of Sprays on Blossoms in Different Stages

In the 1944 experiments with Golden Delicious, the sprays applied at full bloom were generally more effective in reducing fruit set than those applied at late full bloom. However, the results with Grimes Golden in 1944 and those obtained in 1943 are not conclusive in this respect. Rain occurring 2 hours after the late-bloom applications on Golden Delicious may have been a factor in reducing the effectiveness of the sprays. McDaniels and Hildebrand (3) have pointed out that Elgetol sprays between .1 per cent and .2 per cent concentration function chiefly as pollicides, and blossoms that have been pollinated for a sufficient length of time are not killed by the spray. Since the pollen tube under favorable conditions usually traverses the full length of the style within 48 hours, it would seem that much less reduction in fruit set would have resulted from these sprays than was actually obtained, when applied 48 to 72 hours following full bloom.

In order to obtain additional information on this point in 1943, several thousand blossoms in different stages of development were tagged and sprayed with 0.15 per cent Elgetol. In all cases fruit set was less where freshly opened blossoms were sprayed than where blossoms were sprayed 3 to 4 days after opening. Yet the high degree of set reduction that was obtained in the latter class of flowers would seem to indicate that many of these flowers that had apparently been pollinated and fertilized prior to the spray application failed to set fruit as a result of the spray treatment.

Data obtained in 1944 on the effect of Elgetol on fruit setting from blossoms sprayed in different stages of development are shown in Table V. With Grimes Golden, reduction in set as a result of the spray treatments seemed to be due largely to a greater number of blossom clusters failing to set fruit, rather than to a thinning of individual clusters with a tendency of the center blossom to resist killing. With Golden Delicious, however, the data suggest a greater percent-

TABLE V—EFFECT OF ELGETOL SPRAY ON FRUITING HABIT OF BLOSSOMING SPURS OF GRIMES GOLDEN AND GOLDEN DELICIOUS APPLES. 1944

Spray Concentration (Per Cent)	Stage of Bloom	Number Fruits Per 100 Blossoming Spurs	Number Fruits Per 100 Fruiting Spurs	Fruits Originating From Center Blossoms (Per Cent)	Blossom Spurs Not Fruiting (Per Cent)
		Grimes Golden			
Check		49.4	120	32.1	59
0.15	F.B.[1]	22.3	118	21.3	81
0.15	L.B.[2]	33.6	110	27.0	69
		Golden Delicious			
Check		54.1	121	45.5	55
0.19	F.B.	28.9	106	50.9	73
0.19	L.B.	38.2	111	54.4	66

[1]Full bloom. [2]Late full bloom.

age of center fruits as a result of spray treatments with a greater number of spurs setting single fruits, particularly when the sprays were applied at full bloom. An important effect of the sprays on this variety, as well as on Grimes Golden, however, was the failure of a greater number of flowering spurs to set any fruit at all, in comparison with the checks.

FOLIAGE AND SPUR INJURY RESULTING FROM SPRAY TREATMENTS

Injury to spurs and spur leaves from the spray treatments used in these experiments was not a serious factor. In most of the experiments no apparent injury to foliage or spurs resulted. In some instances crinkling and mottling of the young developing leaves occurred, with an occasional killing of individual spurs on the lower weak limbs. Injury was not so serious in any case that the trees did not soon recover, with a foliage system apparently as large and as dense as that of unsprayed trees.

DISCUSSION AND SUMMARY

The temperature records in Table I offer a plausible clue in attempting to explain the generally greater reduction in fruit set in 1943 than in 1944 as a result of spray treatments on York Imperial and Grimes Golden. In 1943, during the height of the bloom period, mean temperatures on most days were below 60 degrees F. These relatively low temperatures, coupled with high wind velocity, reduced bee activity and fruit-setting processes to a bare minimum, even on the most favorable days. It may be noted from the data presented that the set of fruit on the check trees of these varieties was more than twice as great under the more favorable conditions that existed in 1944. It seems significant that in 1943 the only orchard (York Imperial, Green Lane Orchard) in which yield was not severely reduced as a result of the spray treatment was located in an area where full bloom was several days later than in the other orchards and occurred under much more favorable conditions of temperature. The more satisfactory results generally obtained in 1944 strongly indicate that

with certain varieties the use of these blossom-thinning sprays is commercially feasible only under conditions favorable for pollination and fruit set. Since such sprays are applied at full bloom or later, fortunately the conditions influencing fruit set are largely known before it becomes necessary to determine the desirability of using a spray for the purpose of fruit thinning.

With Yellow Transparent in 1943 appreciable reduction in fruit set was obtained without overthinning. With this variety a set of 66 to 72 apples per 100 blossoming spurs was obtained on the unsprayed trees. Thus it would seem that Yellow Transparent is in a class with Wealthy and Oldenburg (4) with respect to its ability to set fruit under adverse conditions.

With respect to spray concentrations, there seems to be no significant difference in effectiveness within the range tested. It would seem unnecessary under most conditions prevailing in the area where these tests were conducted to use a blossom-thinning spray stronger than 0.2 per cent Elgetol on the varieties included in this study.

The results with dinitro-ortho-cresol powder (DN Wettable No. 2) gave essentially the same results as sodium dinitro-cresylate (Elgetol) when used with equivalent concentrations of toxicant. One test with the amine salt of dinitro-ortho-cresol (DN No. 111) showed promise as a material for blossom thinning.

Although the sprays applied at full bloom to Grimes Golden and Golden Delicious were somewhat more effective than those applied 32 to 72 hours following full bloom, the significant reduction in fruit set from the later sprays indicates that a large number of flowers already fertilized may be killed by these sprays.

While foliage injury in these tests was not a serious factor, there was some suggestion that the late sprays resulted in less leaf injury.

In these studies high tree vigor was not necessarily associated with less effectiveness of spray treatment, as Hoffman has previously reported under New York conditions (2). In many instances less thinning was accomplished with spray treatments on trees of low vigor, suggesting that the conditions or causes responsible for a particular state of vigor may be important factors in determining the response of certain trees to blossom-thinning sprays.

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Retardation of Pre-harvest Drop of Apples Through Aerosol Application of Growth-regulating Substances[1]

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A summary statement has been made regarding the aerosol application of growth regulators to retard the abscission of apple fruits (5). The present paper presents more fully the data upon which the preliminary announcement was based. Since the principles of aerosol application have already been discussed (2, 3, 4), they need not be repeated here.

Materials and Methods

Dwarf and semi-dwarf trees of the McIntosh, Macoun and Kendall varieties were used in the test—varieties that do not retain the fruit well. The trees were 8 and 9 years old, those of the McIntosh variety being on the Malling V and VI rootstocks, the Macoun on Malling I and IX, and the Kendall on Malling I. The Macoun trees on Malling IX were 5½ feet in height and 6 feet in spread, and averaged 1 bushel of fruit per tree in 1944, the year of the experiment. The varieties on Malling I, V, and VI were approximately 12½ feet in height and 10 feet in spread, and averaged about 2.5 bushels of fruit per tree. All trees were in good state of vigor, growing in the Experiment Station orchard at Geneva, New York, in a system of sod mulch with applications of nitrogenous fertilizers.

Naphthalene acetic acid was the growth-regulating substance used. It was applied in three forms, as follows:

1—Aerosol form, consisting of .25 per cent naphthalene acetic acid, 5 per cent lanolin, and 94.75 per cent dimethylether, applied from a "Sure Shot Sprayer" weighing about 2 pounds.

2—In a water spray at 10 ppm, carried in .5 per cent Carbowax 1500, applied from a 3-gallon knapsack sprayer.

3—In a water spray at 10 ppm, carried in .5 per cent ethyl alcohol, applied from a 3-gallon knapsack sprayer.

Exactly 1 pound of material was prepared for each aerosol application. Accordingly, .04 ounce (.25 per cent) of naphthalene acetic acid was dissolved in .8 ounce (5 per cent) of lanolin. One of the fittings was then removed from the "Sure Shot Sprayer", these materials poured into the cylinder through the opening, and the fitting replaced. The large metal cylinder of liquid dimethylether was fitted with a common tire-fitting outlet; the Sure Shot Sprayer comes equipped with a common pneumatic tire valve. The valve of the sprayer was pressed into the tire-filling outlet of the large cylinder, so that the dimethylether flowed under pressure over into the sprayer.

The sprayer was weighed before being filled and then re-weighed several times as additional amounts of dimethylether were injected

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into it until the increase in weight reached 1 pound. To expedite the flow of dimethylether, the large metal cylinder was warmed with warm water and then was inverted so that any free gas in the cylinder was at the upper end and so forced the liquefied gas into the sprayer. Dimethylether is explosive at high concentrations, and it has anesthetic properties; filling is best done out-of-doors or in an unconfined space with full recognition of the possible dangers involved.

The measured amount of Carbowax 1500 was melted and the naphthalene acetic acid stirred into it. The mixture was then poured into the 3-gallon sprayer.

Approximately ⅓ (.34) of a gallon of water spray was used for each bushel of fruit at each application, and ½ ounce (.034 of a pound) of aerosol. In terms of naphthalene acetic acid, 13.8 mgs were used per bushel of fruit in each application of water spray, and 34 mgs in each aerosol application. In commercial practices the recommendation of 1 gallon of spray at 10 ppm for each bushel of fruit is equivalent to 40 mgs per bushel.

Both single and repeat applications were made as follows:

1—Single applications of naphthalene acetic acid in aerosol form and carried in Carbowax 1500 and in ethyl alcohol, to trees of McIntosh on September 12.

2—Repeat applications of naphthalene acetic acid, in aerosol form and carried in Carbowax 1500 and ethyl alcohol, to trees of McIntosh, Macoun and Kendall at 7-day intervals—September 18, September 25, October 3, and October 10.

3—Single application of 2,4-dichlorophenoxyacetic acid in aerosol form to trees of Kendall on September 25.

The dates of commercial harvest for these varieties were: McIntosh, September 19; Macoun, September 25; and Kendall, September 25.

Because of the small size of the trees and the concentration of fruit in an accessible position it was possible to apply both the aerosol and the water sprays directly onto the fruit from a distance of only a few feet. Excellent coverage of the fruit was secured, and less material may have been used than would have been the case had all the foliage been thoroughly covered, as well as the fruit. Average mean temperatures on the days of application were: 68 degrees F on September 12, 69 degrees F on September 18, 54 degrees F on September 25, 58 degrees F on October 3, and 55 degrees F on October 10.

All drop fruits were gathered from under the trees before the sprays were applied. The drops were counted and weighed at regular intervals, and totalled to give the figure of total yield for each tree.

I. Results With Single Applications in Aerosol Form and in Water Sprays

Three McIntosh trees were sprayed with naphthalene acetic acid carried in Carbowax 1500, three sprayed with naphthalene acetic acid carried in ethyl alcohol, two treated with naphthalene acetic acid in

aerosol form, and three unsprayed. Applications were made September 12, 1944, 7 days before the date of commercial harvest for the variety.

There was very little dropping of fruit from any of the eleven trees, regardless of treatment, during the 10 days following application. On September 22, 10 days after treatment, and 3 days after the commercial picking date for the variety, 91 per cent of the fruit still remained on treated trees and 88 per cent on untreated trees. The differences were not large during the remainder of the season between treatments or between treated and untreated trees, as shown in Table I. However, the drop was slightly less on treated trees, and the treatment with Carbowax 1500 as the carrier was slightly the best. Considered in conjunction with the data from experiments which follow, they emphasize the importance of timing, as has been shown by Batjer (1) and others.

TABLE I—Percentage of McIntosh Apples Remaining on Trees Following a Single Application of Naphthalene Acetic Acid, Prepared in Carbowax 1500 and in Ethyl Alcohol. Application September 12, 1944, 7 Days Before the Date for Commercial Harvest of the Variety

Treatment	Trees (No)	Average Yield Per Tree (Bushels)	Crop Remaining on Tree at Dates Given (Per Cent)				
			Sep 22	Sep 27	Oct 10	Oct 12	Oct 22
Control	3	2 2	88	81	74	36	0
Aerosol Method	2	2.5	91	81	64	34	0
Carbowax Carrier	3	2 4	91	82	77	47	0
Alcohol Carrier	3	2.3	91	88	81	41	0

II. Results With Repeat Applications in Aerosol Form and in Water Sprays

McIntosh:—Three McIntosh trees were sprayed on September 18 with naphthalene acetic acid carried in Carbowax 1500, three with the same growth-regulating substances carried in ethyl alcohol, and three treated with naphthalene acetic acid in aerosol form. Three additional applications were made at 7-day intervals, on September 25, October 3, and October 10. The responses from all three treatments were similar. The results are shown in Table II, and represented graphically in Fig. 1. On October 12 (23 days after commercial harvest) approximately three-fourths of the crop remained on the treated trees, regardless of treatment, as compared with approximately one-third of the crop remaining on untreated trees. By October 22, (34 days after commercial harvest) no fruit remained on untreated trees, whereas 14 to 23 per cent remained on treated trees on that date. On October 30 (41 days after commercial harvest) 12 per cent still remained on the trees.

Kendall and Macoun:—Two trees of Kendall and three of Macoun were treated with naphthalene acetic acid in aerosol form on Septem-

ber 18, and three times more at 7-day intervals on September 25, October 3, and October 10. Three trees of each variety were left untreated as controls.

TABLE II—PERCENTAGE OF McINTOSH, MACOUN, AND KENDALL APPLES REMAINING ON TREES FOLLOWING FOUR APPLICATIONS OF NAPHTHALENE ACETIC ACID, PREPARED IN CARBOWAX 1500, IN ETHYL ALCOHOL, AND IN AEROSOL FORM. APPLICATIONS ON SEPTEMBER 18 AND 25, AND OCTOBER 3 AND 10, 1944

Treatment (Carrier)	Trees (No)	Average Yield Per Tree (Bushels)	Crop Remaining on Trees at Dates Given (Per Cent)				
			McIntosh—Commercial Harvest, Sep 19				
			Sep 23	Oct 2	Oct 12	Oct 22	Oct 30
Control	9	2.4	85	73	36	0	0
Aerosol	3	2.5	87	84	75	17	12
Carbowax	3	2.6	87	85	78	23	12
Alcohol	3	2.3	87	83	74	14	12
			Kendall—Commercial Harvest, Sep 25				
			Sep 23	Oct 2	Oct 12	Oct 22	Oct 30
Control	3	4.0	88	76	26	16	2
Aerosol	2	4.2	96	94	94	89	87
			Macoun—Commercial Harvest, Sep 25				
			Sep 23	Oct 7	Oct 17	—	Oct 31
Control	3	4.1	83	72	33	—	4
Aerosol	3	4.3	83	74	56	—	27

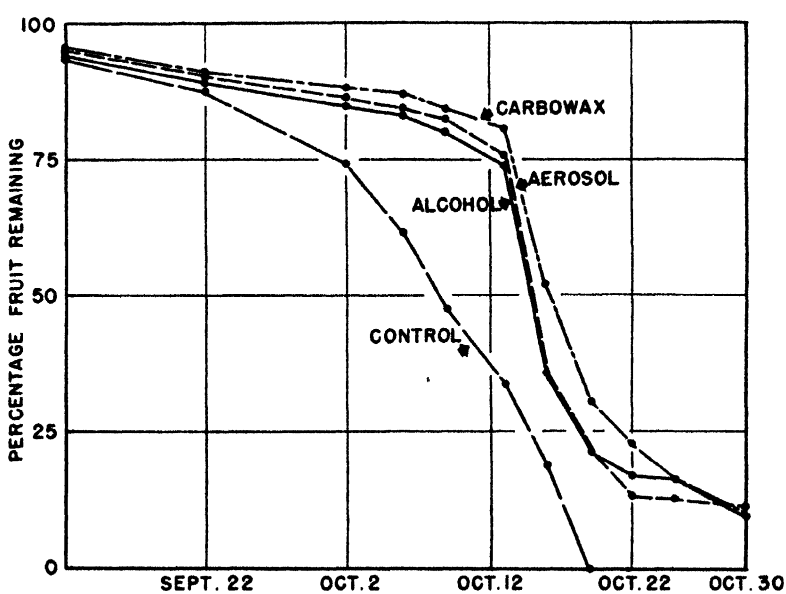

FIG. 1. Percentages of McIntosh apples remaining on trees following four applications of naphthalene acetic acid prepared in Carbowax 1500, in ethyl alcohol, and in aerosol form. Applications September 18 and 25, and October 3 and 10.

The aerosol applications were effective with both varieties. The results are given in Table II. With the Macoun variety there was little difference between the treated and untreated trees, following the applications of September 18 and 25. By 22 days after the date of commercial harvest and following four applications (September 18 and 25, and October 3 and 10), 56 per cent of the fruit remained on treated trees as compared with 33 per cent on untreated trees. By October 31 (36 days after commercial harvest) 27 per cent of the fruit remained on treated trees as compared with 4 per cent on untreated trees.

With the Kendall variety the treatments were especially effective. The initial application on September 18 resulted in immediate retardation of fruit drop so that on September 23 (5 days after treatment), 96 per cent of the fruit remained on treated trees as compared with 88 per cent on untreated. The drop from untreated trees continued steadily until on October 30 (35 days after treatment) only 2 per cent of the fruit remained on the trees, whereas on treated trees 87 per cent of the fruit remained. Many of adhering Kendall fruits were cracked and split by this date (Fig. 2).

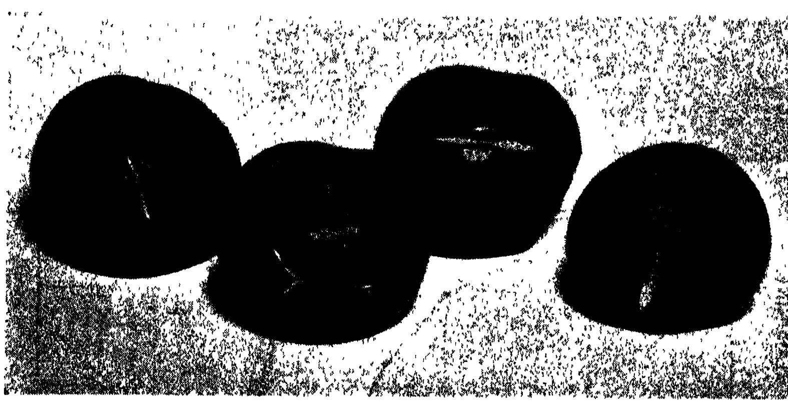

FIG. 2. Kendall fruits which remained on the tree 36 days beyond the date of commercial harvest following four applications of naphthalene acetic acid in aerosol form at 7-day intervals showing checking and splitting.

Macoun/Malling IX:—Repeat aerosol applications of naphthalene acetic acid were made to one of two adjacent dwarf trees of Macoun on the Malling IX rootstock on September 18 and 25 and October 3 and 10. The trees were 9 years old, 5½ feet in height, 6 feet in spread, and carried about 1 bushel of fruit. The fruit on both the treated and the untreated trees adhered well and there were no apparent differences between treatments. On October 31 (36 days after commercial harvest) 66 per cent of the fruit still remained on treated trees and 60 per cent on untreated trees.

These figures compare with 4 per cent remaining on untreated trees on the Malling I rootstock. It has been observed in the course of study at this Station that fruit adheres especially well to trees on the

Malling IX rootstock. Such trees are not overly vegetative, in contrast to the greater vigor of trees on the Malling I rootstock.

III. Results With a Single Aerosol Application of 2,4 Dichlorophenoxyacetic Acid

A single application of 2,4 dichlorophenoxyacetic acid in 5 per cent lanolin and 94.75 per cent dimethylether was made to one tree of Kendall on September 25, 1944. There were 349 apples on the tree. The fruit adhered well, and on October 30 (35 days after the date of commercial harvest for the variety), 152 apples or 43 per cent still remained, as compared with 2 per cent on untreated trees. The fruits were more brightly and more completely colored than on untreated trees, especially those fruits which were in close proximity to the point of aerosol application.

Discussion

The fact that applications of growth-regulating substances either in water sprays or in aerosol form were relatively ineffective in the first experiment with the McIntosh variety, emphasizes the importance of proper timing. Although the applications were made 7 days before the date of commercial harvest, they were evidently applied too early to secure the maximum response under the conditions of the season. The applications which were made at four weekly intervals beginning 1 day before the date of commercial harvest, however, proved very effective.

No attempt was made to be economical with material in the aerosol treatment or to determine minimum requirements; the cylinder was merely exhausted at each application. It may be that the amounts used were in excess of what was required. Nevertheless, even at the relatively high concentration of 40 mgs of growth-regulating substance per bushel of fruit as used in commercial orchard spraying, 1 pound of aerosol containing .25 per cent of growth-regulating substance is equivalent to 28¼ gallons of water spray containing 10 ppm of growth-regulating substance.

The aerosol method of applying growth-regulating substances for the prevention of pre-harvest drop of fruit on relatively small trees is both easy and efficient. The favorable response from repeat application is of interest in this connection. It suggests the possibility of applying small amounts of materials other than growth-regulating substances, as insecticides and fungicides, to small and easily accessible plant materials as dwarf apple trees (5). It suggests also the possibility of adapting the method to larger operations by proper mechanical means.

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Relative Effectiveness of Sprays, Dusts and Aerosols of Naphthalene-Acetic Acid on Harvest Drop of Apples

By P. C. Marth, L. P. Batjer, and H. H. Moon, *U. S. Department of Agriculture, Beltsville, Md.*

Much interest has been manifested in the use of dusts for harvest-drop control because of the rapidity and uniformity with which applications can be made. Hoffman *et al.* (1) have reported that results with dusts on McIntosh apples were generally as good under New York State conditions as with liquid sprays. Under conditions prevailing in Massachusetts, Southwick (4), however, found dusts to be generally less effective than sprays in controlling apple fruit drop. The present report contains results comparing the effect of aqueous sprays containing naphthaleneacetic acid with the effect of naphthaleneacetic acid in different types of dust carriers or in aerosol form, in controlling the harvest-drop of Stayman Winesap apples.

Methods

The trees used in this experiment were 13 years old and in good vigor. They were located in the Station orchard at the University Experiment Farm, Kearneysville, West Virginia. Each treatment (Fig. 1) consisted of 12 trees (8.0 bushels of fruit per tree average), randomized throughout the experimental block.

Approximately 12 to 15 gallons of solution were applied to each tree that received the spray treatments. About 1½ pounds of dust mixture containing 0.1 per cent naphthaleneacetic acid in talc was used on each tree that received the dust treatments. Since 1½ pounds of this dust contained approximately the same amount of naphthalene-acetic acid as 15 gallons of .001 per cent spray, it would seem that with these treatments practically equivalent amounts of active ingredient were applied with the two methods. With the .0005 per cent spray, proportionately less, and with the 0.2 per cent dust, proportionately more naphthaleneacetic acid per tree was used.

In aqueous solutions, Carbowax 1500 (a polyethylene glycol) has markedly increased the effectiveness of growth-regulating substances when applied to young bean plants (3). A simple procedure was devised for incorporating Carbowax 1500 at 0.3 per cent concentration with talc dust containing naphthaleneacetic acid. This was accomplished by making separately a thin paste of weighed amounts of the dust and of Carbowax dissolved in 95 per cent ethyl alcohol, and then stirring the two together. After drying at 80 degrees C the material was further mixed and passed through the air intake of an ordinary vacuum cleaner in order to mix more thoroughly and to restore fluffiness. The material was then removed from the bag of the vacuum cleaner and stored in airtight containers.

Aerosols of naphthaleneacetic acid and liquified gas were prepared in small steel cylinders, according to the method described by Marth and Meader (2). Approximately 1¼ pounds of the aerosol (con-

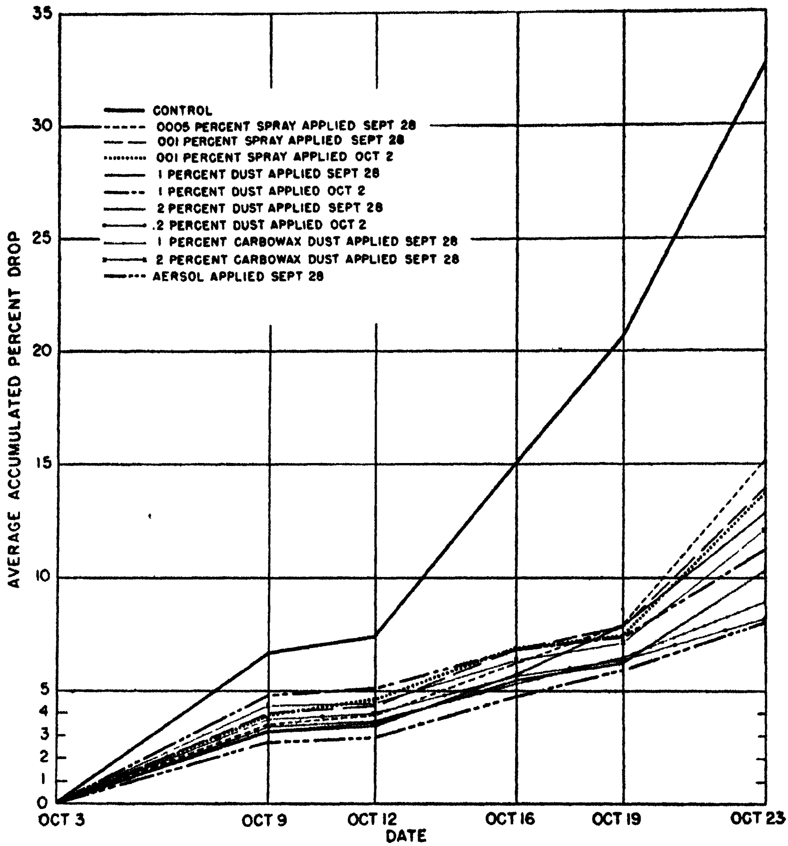

FIG. 1. Graph showing the relative effectiveness of aqueous sprays, dusts, and liquified-gas aerosols of naphthaleneacetic acid in preventing the harvest drop of Stayman Winesap apples. Average (12 trees) accumulative fruit drop following each indicated treatment.

taining the equivalent amount of naphthaleneacetic acid in 15 gallons of .001 per cent spray) was used per tree. In applying the aerosol a nozzle was attached to the cylinder and an attempt was made to direct the fog so that it would contact most of the fruits. The fruits in the upper portion of the tree were treated by attaching the cylinder to one end of a 10-foot pole.

The dust treatments were applied in early morning (on the dates indicated in Fig. 1) to take advantage of a moderately heavy dew. Temperature during applications varied from 55 to 65 degrees F. The spray and the aerosol treatments were applied from 10:00 a. m. to 12:00 noon, with temperature varying from 70 to 75 degrees F. A light rain, which started on September 28 at 1:00 p. m., continued intermittently until the evening of September 30. A total of 0.3 inches of precipitation occurred during this period. On October 3, 0.62

inches of rain fell, beginning in early morning and ending in late afternoon.

Fruit drop records were made at frequent intervals following the application of experimental treatments. The fruit was harvested on October 23, 25 days after the treatments of September 28 and 21 days after the treatments of October 2.

Experimental Results

Accumulated percentages of fruit drop following the various experimental treatments is shown in Fig. 1.

All treatments were significantly effective in retarding fruit drop. The dust treatments, as a whole, were somewhat more effective than the spray treatments, though these differences are not regarded as significant, except possibly the 0.1 per cent dust containing Carbowax applied on September 28 and the 0.2 per cent dust without Carbowax applied October 2.

On both dates of application the 0.2 per cent dust treatment proved a little more effective than the weaker dust, though the differences are not regarded as significant. The addition of Carbowax to the dust gave no increase in effectiveness.

The aerosol treatment, as shown in Fig. 1, was among the most effective treatments in controlling fruit drop.

Discussion

Under the conditions of these experiments, application of naphthaleneacetic acid in dust form was at least as effective if not more effective in retarding fruit drop than were liquid sprays. In this instance, doubling the amount of naphthaleneacetic acid contained in the dust slightly increased the effectiveness, but the small added benefit would not seem to be sufficient to justify the added expense. In recent experiments (3) (not concerned with fruit drop) the addition of Carbowax to growth-regulating sprays has resulted in a rather marked increase in effectiveness. In the present experiment there appeared to be a slight tendency for increased effectiveness due to Carbowax in the 0.1 per cent dust; however, the hygroscopic properties of this material failed to increase the effectiveness of the dust in the magnitude that was originally hoped. It is possible that the light 48-hour rain that occurred soon after applications were made tended to minimize any beneficial effect that might have accrued under less humid conditions. Further testing of the value of Carbowax and materials of similar properties, for the possibility of increasing the effectiveness of dusts, would seem worthwhile.

The high degree of effectiveness obtained with naphthaleneacetic acid in aerosol form is of considerable interest. In applying this treatment there was no visible indication that all of the fruits were being contacted with the fog that was emitted from the nozzle. The possibility is suggested that the application of naphthaleneacetic acid by this method in a relatively high concentrated form may have resulted in a limited systemic effect.

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Effect of Naphthaleneacetic Acid Spray on Maturity of Apples

By L. P. Batjer and H. H. Moon, *U. S. Department of Agriculture, Beltsville, Md.*

With the first use of harvest sprays on apples and pears, extensive observations indicated that in some instances advanced fruit maturity was associated with the use of these sprays. Whether this observed effect on ripening was a direct stimulatory effect of the chemical or an apparent difference due to the decreased drop of mature fruit was difficult to establish. From three years of storage testing of a number of fall and late-fall apple varieties Haller (2) concluded that apples given harvest sprays with naphthaleneacetic acid did not show any direct or indirect effect of the sprays on the firmness of the fruit, decay, or breakdown, in comparison with unsprayed apples picked at the same time. Recent work of Gerhardt and Allmendinger (1), however, indicated that when the harvest of Delicious apples and especially of Bartlett pears was deferred as long as two weeks after optimum picking maturity by the application of harvest sprays, the sprayed fruits were considerably more mature and the storage quality seriously impaired. The authors point out that this increase in ripeness was a direct stimulatory effect of the spray chemical and was not an indirect result of the difference in the amount of fruit drop from the sprayed and unsprayed trees. These workers reported no appreciable effect of these sprays on the maturity of Winesap apples.

Some preliminary work and observations at Beltsville, Md., have indicated that season of maturity of apples may be closely related to this problem. It was therefore the purpose of the present experiments to determine the spray-maturity relationships on several varieties of apples maturing from midsummer to late fall.

Methods

Apple varieties used in these studies, listed in order of maturity dates, were as follows: Close (July 1); Williams (July 19); Duchess of Oldenburg (July 23); Summer Rambo (September 2); Jonathan (September 20); Delicious (September 25); and Rome Beauty (October 17). All treatments involving a single spray application of .001 per cent naphthaleneacetic acid were applied from 12 days to 3 weeks prior to the harvest date of the particular variety. In the repeated spray treatments, from two to six applications were made, depending upon the variety. In all repeated spray treatments, the last spray application was made on the same date as the single-spray treatment on other plots, and all previous applications in these treatments were at approximately 2-week intervals. The number of trees per treatment varied from two to eight with the different varieties.

With Close, Williams, Duchess, and Summer Rambo the fruit at harvest was graded into three to four classes, depending upon its maturity. A sample of fruit from each class was tested for firmness

of flesh by means of a standard apple pressure tester. In order to obtain a more direct reading on the effect of treatment on maturity, an attempt was made to reduce fruit drop on Summer Rambo to a minimum by frequent "spot picking" in order to remove the fruits from the tree as they matured. Two- to four-bushel samples from each treatment of this variety, as well as of Jonathan, Delicious, and Rome Beauty, were stored at 32 degrees F for certain intervals and post-ripened at 70 degrees F for 1 week. These fruits were then pressure-tested and examined for storage disorders.

Results

Results of these experiments on the Close, Williams, and Duchess varieties are shown in Table I. Due to the limited number of trees available of these varieties, the data for individual trees are presented.

TABLE I—Effect of .001 Per Cent Naphthaleneacetic Acid Spray on Maturity of Close, Williams, and Duchess Apples

Tree No.	Treatment	Per Cent Drop	Stage of Fruit Maturity at Harvest					
			Firm		Medium Firm		Ripe and Overripe	
			Per cent*	Pounds Pressure	Per cent*	Pounds Pressure	Per cent*	Pounds Pressure
			*Close Variety***					
1	Check	54.1	27.2	21.0	6.6	13.0	12.1	—
3	Check	25.5	57.4	20.0	6.7	13.0	10.4	—
2	Spray	13.3	12.0	15.0	9.9	8.0	64.8	—
4	Spray	11.0	35.3	20.0	12.9	12.0	40.8	—
			Williams Variety†					
8-19	Check	60.2	22.1	16.9	15.6	10.8	2.1	7.0
6-19	Check	35.8	48.7	18.3	12.4	12.3	3.1	7.5
4-19	Check	38.0	40.0	17.9	17.6	13.0	4.4	9.0
7-19	Spray	0.6	0.0	—	26.2	9.2	73.2	6.6
5-19	Spray	1.4	7.7	14.9	34.6	7.5	56.2	5.8
3-19	Spray	0.4	18.0	15.6	32.5	10.0	49.1	7.4
			Duchess Variety‡					
5-7	Check	20.2	56.1	16.3	21.2	15.2	2.5	12.2
2-7	Check	39.0	43.0	16.6	16.7	15.8	1.3	9.6
6-7	Spray	4.0	34.4	15.7	27.9	13.7	33.7	8.8
1-7	Spray	10.6	32.1	15.4	28.2	12.6	29.1	6.3

*All percentages on basis of number of fruits on trees at time of spray applications.
**Sprayed June 19, 1944; harvested July 1, 1944.
†Sprayed July 8, 1944; harvested July 19, 1944.
‡Sprayed July 8, 1944; harvested July 21, 1944.

Judging from the difference shown in percentage of ripe fruit, the spray treatment resulted in a large apparent increase in fruit maturity. It should be pointed out, however, that a large percentage of the sprayed fruits remained on the tree that would have dropped had the spray not been applied. Naturally these fruits were among the most mature, and when harvested were, to a large degree, classified as ripe fruit. In all three varieties, however, the difference in drop between check and sprayed trees (even though great) was not sufficient to account for the even greater differences obtained in ripe fruit. A better

measure of the stimulatory effect of the spray on fruit maturity is shown in the percentage of firm fruit the trees carried at harvest (Table I). Again, these data in most cases show that a lower percentage of fruits from the sprayed trees were classified as firm. If any fruits had dropped from the untreated trees that would have been ultimately classified as immature or firm, this difference would obviously have been greater. The amount of firm fruits at harvest, expressed as a percentage of the original crop, is therefore the better measure of the effect of the treatment on fruit maturity, since this method of expression tends to minimize any indirect effect of retardation in fruit drop.

Further substantiating evidence that the sprays directly advanced the fruit maturity of these varieties is shown by the greater firmness (as measured by a pressure tester) of fruit from the check trees in all three maturity classes. Here again, however, the greatest significance should be attached to the firm class, since the ripe and perhaps the medium class contained fruits that otherwise would have dropped from the tree had the spray treatment not been applied.

In the case of the Summer Rambo variety, the data in Table II represent an average of nine trees per treatment. As mentioned above,

TABLE II—EFFECT OF .001 PER CENT NAPHTHALENEACETIC ACID SPRAY ON MATURITY OF SUMMER RAMBO APPLES

Treatment	Per Cent Fruit Drop	State of Fruit Maturity at Harvest					Fruit Firmness and Decay After Storage			
		Firm		Medium Firm		Ripe	Firm		Medium Firm	
		Per Cent	Pounds Pressure	Per Cent	Pounds Pressure	Per Cent	Pounds Pressure	Per Cent Decay	Pounds Pressure	Per Cent Decay
Check	26.0	57.7	15.9	14.7	12.7	1.6	9.1	32.5	8.8	53.3
Sprayed Aug 8	11.2	65.0	15.1	19.4	11.2	4.4	9.4	26 5	8.8	57.4
Sprayed Jul 25 and Aug 8	9.9	65.8	15.5	18.3	12.2	6.1	9.4	26.2	8.5	45.7

these trees were "spot" picked on August 15, 21, and 27, and harvest was completed September 1. Fruits from the final picking were stored at 32 degrees F until October 17. After being held for one week at 70 degrees F, the fruits were pressure-tested and scored for decay. As may be seen from Table II, there seems to be no indication, in general, that the naphthaleneacetic acid sprays had any direct stimulatory effect on maturity of this variety. Actually the untreated trees had a slightly lower percentage of fruits classified as firm than was recorded for the sprayed trees. In the stored fruit, firmness (as measured by a pressure tester) and percentage of decay were essentially the same for all treatments. There is a slight suggestion, however, that the fruit from the check trees was somewhat firmer at harvest than fruits of the same class receiving the spray treatments.

The results for Jonathan, Delicious, and Rome Beauty apples are presented in Table III. In the case of the Jonathan and Rome Beauty varieties, it may be seen that neither the prolonged spray treatment nor the single spray application had any effect, direct or indirect, in

TABLE III—EFFECT OF .001 PER CENT NAPHTHALENEACETIC ACID SPRAY ON MATURITY OF JONATHAN, DELICIOUS, AND ROME BEAUTY APPLES

Treatment	Number of Trees Per Treatment	Accumulated Per Cent Fruit Drop	Fruit Condition After Storage				
			Pounds Pressure	Per Cent Sound	Per Cent Decay	Per Cent Breakdown	Per Cent Storage Scald
			Jonathan†				
Check. .	6	32	—	94.6	3.0	2.3	0
Repeat spray*	6	13	—	93.5	2.9	3.6	0
			Delicious‡				
Check.	8	30	10.9	64.0	3.7	0	32.3
Single spray**	8	9	11.0	84.6	3.7	0	11.7
Repeat spray*	8	3	10.7	82.8	5.5	0	11.7
			Rome Beauty§				
Check. . .	8	29	11.5	94.2	4.7	1.1	0
Single spray**	8	20	11.8	93.1	5.9	1.0	0
Repeat spray*	8	6	11.4	94.1	4.9	1.0	0

*Jonathan sprayed July 25, August 8 and 19, September 1; Delicious sprayed July 25, August 8 and 19, September 1 and 15; Rome Beauty sprayed July 25, August 8 and 19, September 1 and 15, and October 2.

**Delicious sprayed September 15; Rome Beauty sprayed October 2.

†Jonathan harvested September 11, stored at 31 degrees F until December 19, and postripened for 7 days at 70 degrees F.

‡Delicious harvested September 25, stored at 31 degrees F until January 11, and postripened for 70 days at 70 degrees F.

§Rome Beauty harvested October 17, stored at 31 degrees F until January 27, and postripened for 7 days at 70 degrees F.

advancing fruit maturity. The very slight difference in increase of breakdown and decay following the naphthaleneacetic acid treatments, if not experimental error, may well be accounted for by an occasional over-mature fruit remaining on the tree that would have dropped had the sprays not been applied. The relatively high fruit drop shown for the single-spray treatment on Rome Beauty was due to the fact that a 14 per cent harvest drop had already occurred when the spray was applied on October 2.

With the Delicious variety, the much lower percentage of sound fruit in the check treatment was the result of a greater amount of storage scald. This variety was stored without shredded oil paper, and the high percentage of scald would indicate that the fruit was harvested somewhat ahead of its optimum maturity. Since only about one-half of the difference in amount of scalded fruit, as between the treated and the untreated Delicious trees, can be accounted for by the greater dropping of mature fruit from the unsprayed trees, these results would suggest a slight stimulatory effect of the sprays, even though such an effect was not sufficient to be reflected in firmness of fruit, decay, or breakdown.

DISCUSSION

Results of these studies clearly indicate a direct stimulatory effect of naphthaleneacetic acid spray on such summer varieties of apples as Close, Williams, and Duchess of Oldenburg. Such an effect may be due to the softer nature and limited keeping qualities of these varieties, but the relatively high temperatures generally prevailing when

such fruits reach their maturity period may also be a contributing factor. The data presented support in general the conclusions of Gerhardt and Allmendinger (1) and suggest that these summer varieties of apples are similar to Bartlett pears in their response to this spray. However, the effect on maturity of Delicious was less marked than reported by these authors, even when as many as five spray applications were made at intervals from July 25 to September 15. In the present experiment, Delicious were picked at optimum maturity, whereas those studied by Gerhardt and Allmendinger were left on the trees until past best picking condition. With the Delicious variety, as well as Summer Rambo, Jonathan, and Rome Beauty, results confirm those of Haller (2), who concluded that there was no direct effect of naphthaleneacetic acid spray on subsequent firmness of fruit, decay, or breakdown of fall and late-fall varieties of apples when picked at approximately the best maturity for storage holding.

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The Influence of A-Naphthaleneacetic Acid Spray on the Maturity and Storage Physiology of Apples, Pears, and Sweet Cherries

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ABSTRACT

The complete paper will be published in the *Journal of Agricultural Research.*

INVESTIGATIONS on the influence of pre-harvest applications of a-naphthaleneacetic acid on the maturity and storage physiology of Winesap and Delicious apples, Bartlett pears, and Bing cherries were conducted at Wenatchee, Washington, during 1941 to 1943.

The growth chemical in a concentration of 0.001 per cent was usually applied, from 4 to 7 days prior to harvest, on one or more main leaders of the experimental trees. Records were kept of the fruit drop and the degree of ripeness of both the attached and the dropped apples and pears. Pickings were generally made over a maturity range occurring between 10 to 30 days from the time of application of the hormone spray. Experimental fruit from each of the test trees was stored at temperatures of 31 degrees and 36 degrees F. For ripening and physiological studies, respiration, soluble pectin, firmness, and organic volatile measurements were made on these samples at irregular intervals during storage.

A-naphthaleneacetic acid reduced the harvest drop of Winesap and Delicious apples and of Bartlett pears to approximately one-fourth that of the unsprayed fruit. No increase in ripening or impairment of storage quality could be attributed to the effect of the spray when the fruit was harvested from 10 days to 2 weeks following the date of its application.

In Bartlett pears, and to a lesser extent in Delicious apples, deferred harvest of longer than 2 weeks caused a greater increased ripeness and a more seriously impaired storage quality in the hormone-sprayed than in the unsprayed fruits.

Psysiological analyses and the development of core break-down in the various lots of stored pears showed that a-naphthaleneacetic acid stimulated ripening when the sprayed fruit was permitted to hang on the trees for extended periods prior to harvest. Data are presented to show that this stimulatory effect on ripening is a direct consequence of the chemical itself rather than an indirect result of the difference in the amount of fruit drop from the sprayed and control leaders.

The moisture content, turgidity, and greenness of the stems of Bing cherries during storage could not be correlated with the harvest application of the hormone spray.

The Relation of the Time Factor to the Influence of Concentration of Wax Emulsion on the Reduction of the Rate of Transpiration of Apples[1]

By S. A. Pieniazek and E. P. Christopher, *Rhode Island Agricultural Experiment Station, Kingston, R. I.*

Beneficial effects of some wax emulsions on the incidence of bitter pit, scald, and Jonathan Spot have been reported (1, 3), but the main purpose of waxing is still the reduction of the rate of transpiration and subsequent shriveling. The extent to which the rate of transpiration is reduced depends primarily on the concentration of the wax emulsion.

The relationship between the concentration of wax emulsion and its effectiveness is not a simple one. Platenius (2) found with vegetables that the effectiveness of wax emulsions increases with concentration only to a certain point, and Smock (3) reported a case in which a more dilute emulsion resulted in slightly greater reduction of water loss than a more concentrated one.

Material and Methods

The following wax emulsions, provided by the Franklin Research Company of Philadelphia, Pennsylvania, were used: Brytene 489A, 333B, 284D and 929A. They were diluted with water to obtain desired concentrations. The fruits to be treated were divided into comparable lots of 10 to 25 each, dipped in wax emulsions, and allowed to dry. They were weighed individually and then stored. Waxing was done either at room or at packing house temperatures, varying with the season.

The following varieties of apples were used: Baldwin, Golden Delicious, McIntosh, Rhode Island Greening, and Tompkins County King. The fruits came from the College orchard, except for the Golden Delicious variety, which was provided from Edwin Knight's orchards in Greenville, Rhode Island. Waxed apples were stored in a commercial refrigerated storage, in a home basement storage, and at room temperatures.

The fruits were weighed at regular time intervals, varying from a day to a month, depending on storage temperatures. The loss in weight was identified with the loss of water for the sake of simplicity, although it was realized that some of it was due to the loss of carbon in the respiration process.

Results and Discussion

Cold Storage:—The results obtained with Golden Delicious apples treated with Brytene 489A wax emulsion are given in Tables I and II, and are graphically presented in Fig. 1. It was found that the effectiveness of a given wax emulsion in reducing the rate of transpiration of apples is not constant during the season. Concentrated

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[1]Contribution No. 666 of the Rhode Island Agricultural Experiment Station, Kingston, R. I.

TABLE I—MONTHLY RATES OF TRANSPIRATION OF 25 GOLDEN DELICIOUS APPLES WAXED WITH BRYTENE 489A AND STORED AT 32 DEGREES F

Initial Weight of 25 Fruits (Gms)	Treatment (Gms)	Monthly Rates of Transpiration (Gms)				
		Oct 12–Nov 12	Nov 12–Dec 12	Dec 12–Jan 12	Jan 12–Feb 12	Feb–12 Mar 12
3258.7	Brytene 489A 26	42.1	17.6	14.2	12.3	11.5
3259.3	Brytene 489A 13	38.2	23.3	17.4	15.1	14.5
3260.1	Brytene 489A 6.5	33.5	25.2	23.0	23.4	23.4
3257.0	Brytene 489A 3 25	32.2	28.6	26.5	25.6	26.5
3258.4	Check	35.2	31.0	28.9	29.1	30.7

TABLE II—CUMULATIVE TRANSPIRATION OF GOLDEN DELICIOUS APPLES WAXED WITH BRYTENE 489A AND STORED AT 32 DEGREES F

Initial Weight of 25 Fruits (Gms)	Treatment (Per Cent)	Loss in Weight (Gms)				
		Oct 12–Nov 12	Oct 12–Dec 12	Oct 12–Jan 12	Oct 12–Feb 12	Oct 12–Mar 12
3258.7	Brytene 489A 26	42.1	59.7	73.9	86.2	97.7
3259.3	Brytene 489A 13	38.2	61 5	78.9	94.0	108.5
3260.1	Brytene 489A 6.5	33.5	58 7	81.7	105.1	128.5
3257.0	Brytene 489A 3.25	32.2	60.8	87.3	112.9	139.4
3258.4	Check	35.2	66.2	95.1	124.2	154.9

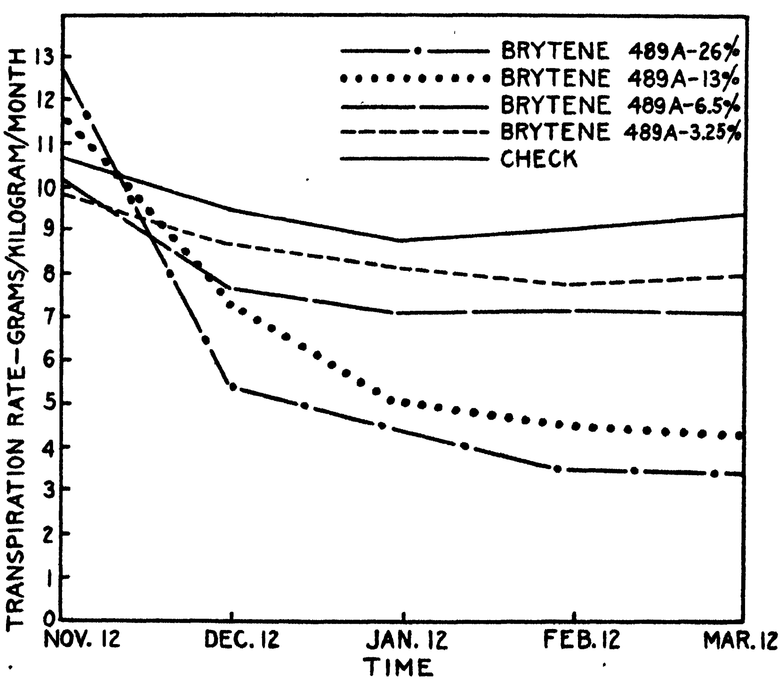

FIG. 1. Monthly rates of transpiration of Golden Delicious apples waxed with Brytene 489A wax emulsions and stored at 32 degrees F.

emulsions cause an increase in the rate of transpiration immediately after the treatment has been given. After some time, however, the rate of transpiration of heavily waxed fruits drops much below that of check and lightly waxed fruits.

Diluted emulsions do not increase the rate of transpiration but their effectiveness also increases with time. The less concentrated the emulsion, the less pronounced is the time factor.

The existence of the above described time factor makes it difficult to formulate a relationship between the concentration of wax emulsion and its effectiveness in reducing the rate of fruit transpiration. It is obvious that any such evaluation would depend on the length of time for which water loss was measured.

From the data given in Table II, we could conclude even after 2 months of storage that a wax emulsion containing 3.25 per cent of solids reduced the rate of transpiration more than an emulsion containing 13 per cent of solids. The longer the time for which loss is measured, the closer and more direct is the relationship between concentration of wax emulsion and its effectiveness.

The results obtained with Golden Delicious apples treated with Brytene 489A wax emulsion and discussed above are typical for waxing experiments. The same variety was treated with three other emulsions previously named. The data obtained were essentially the same as those presented in Tables I and II and Fig. 1, and there is no need to quote them here.

Baldwin, McIntosh, Rhode Island Greening, and Tompkins County King apples were treated with Brytene 489A and Brytene 333B wax emulsion during 1942–1943 and 1943–1944 seasons. The results were similar to those obtained with Golden Delicious apples with the exception that these varieties lose water at lower rates and are not as susceptible to shriveling as is Golden Delicious. The relative reduction in the rate of transpiration due to wax emulsions, however, was similar to those observed with the Golden Delicious variety.

Home Basement Storage:—Baldwin apples were treated on October 15, 1943, with several concentrations of Brytene 489A and Brytene 333B wax emulsions. They were stored in a home storage basement, kept at temperatures ranging from 60 degrees to 40 degrees F, and weighed every week.

The data obtained are similar to those presented in Tables I and II and Fig. 1. The time factor in the influence of concentration of wax emulsion on the reduction of the rate of transpiration of apples was even more pronounced here than in the cold storage. In order to have a clearer picture of the occurring changes, the fruits had to be weighed at shorter time intervals. At these temperatures, it took less time for the establishment of a close relationship between wax concentration and the extent to which the rate of transpiration was reduced.

No alcoholic or other off-flavors were noticed in Baldwin apples treated even with concentrated emulsions (Brytene 489A — 26 per cent and Brytene 333B — 24 per cent). The fruits waxed in mid-October, 1943, and stored in a cellar, were offered to twenty-two

different people for evaluation at the beginning of January, 1944. With two exceptions, they all rated fruits treated with 26 per cent or 24 per cent emulsion, respectively, as best and check apples as poorest. These fruits were firmer than untreated ones (difference 2.5 pounds), as recorded by a Magness and Taylor pressure tester. Fruits waxed with dilute emulsions gave only slightly higher readings than check fruits.

The results with McIntosh and Rhode Island Greening apples that received the same treatments were similar to those obtained with Baldwin as far as the time factor is concerned. No alcoholic or other off-flavors were noticed in fruits treated with concentrated wax emulsions. However, for reasons beyond our control, the fruits used for the experiment were in an advanced state of maturity at the beginning of the test and they were found to be too soft and shriveled for sale at the time of the January testing.

Room Temperature:—All previously named varieties of apples were waxed with Brytene 489A, Brytene 333B and Brytene 284D and kept at room temperature. The existence of the time factor previously described was found to be even more pronounced at room than at cellar temperatures, especially for a few days following application. Under these conditions, the fruits had to be weighed every day or every few days. After a week or two, the reduction of water loss from fruits due to emulsion did not change with time to any great extent.

Summary

It was found that the reduction of the rate of transpiration of apples caused by treatment with wax emulsions of different concentrations is not constant throughout the storage period. High concentrations of wax emulsions increase the rate of transpiration immediately after application. With the lapse of time, however, the rate of transpiration of heavily waxed apples drops much below that of check and lightly waxed fruits. The effectiveness of low concentrations of wax emulsions increases also with time, but it is more constant than that of high concentrations.

Evaluation of the effectiveness of different concentrations of a wax emulsion depends on the elapsed time after application. The longer the period of time after treatment, the closer is the relationship between the concentration of wax emulsion and the extent to which the rate of transpiration is reduced. Application of high concentrations of Brytene 489A emulsion (26 per cent solids), and Brytene 333B (24 per cent solids) for cellar-stored Baldwin apples was found to have no ill effects on their quality. Apples treated in mid-October were found firmer and less shriveled at the beginning of January than the check fruits.

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Effect of Pre-storage Treatments on the Incidence of Scald of Rhode Island Greening Apples[1]

By S. A. Pieniazek and E. P. Christopher, *Rhode Island State College, Kingston, R. I.*

Storage scald, according to the generally accepted hypothesis, is caused by volatile substances given off by the apples (2). Two different approaches have been used in attempts to control the disease. One concentrated on elimination of the scald-producing volatile substances from the air by means of oiled paper (2), by ventilation of storages (2), by air conditioning (10, 11), and possibly by waxing (10). The other ignored the volatile compounds already existing in the storage atmosphere and directed all efforts toward immunization of fruits against scald-producing factors. It was known as early as 1903 (9) that well matured apples did not scald as much as early harvested fruits. It has been known also for a long time that certain treatments influencing fruit metabolism will eliminate scald.

Powell and Fulton (9) kept fruits for nine days in an atmosphere of moist nitrogen at the beginning of the storage season and prevented scald entirely. Brooks, Cooley and Fisher (1) kept fruits in closed jars, opening them from time to time when carbon dioxide accumulated up to 6 per cent. They noticed a decrease in scald. The same investigators (1, 2) by keeping fruits in pure carbon dioxide for a few days prior to storage made them immune or greatly resistant to the disease.

The above-described gaseous treatments were not considered practical, partly because of alcoholic flavors that were produced by prolonged treatments, and mainly because it would be difficult to maintain atmosphere of pure nitrogen or pure carbon dioxide. Brooks, Cooley and Fisher, in concluding their work on carbon dioxide in relation to scald (2), warned storage operators against the possibility of an accumulation of considerable amounts of this gas in storage.

Work on scald control has been carried on at the Rhode Island Agricultural Experiment Station for several years, with special emphasis on factors influencing susceptibility of fruit to the disease. Picking maturity, soil and climactic factors were investigated first (4). The present report gives the results obtained in 1943–44 and 1944–45 with pre-storage treatments directed toward immunization of fruits against scald by changes in fruit metabolism (8).

Material and Methods

The Rhode Island Greening apples used in these experiments were grown in the College orchard at Kingston, R. I. Immediately after picking the apples were brought to the laboratory or storage room and treatments were started the next day. Since the treatments differed in the two seasons during which the work was carried out they will be described separately.

[1]Contribution No. 669 of the Rhode Island Agricultural Experiment Station.

The temperature at which treatments were given fluctuated from one to two degrees in the cold storage room as well as at room temperature. The average temperatures are given in Tables I, II and III. As soon as the treatments were completed the fruits were stored with other apples in an apple storage room and held there until March 31 during the first, and until January 29 during the second season.

TABLE I—THE EFFECT OF CARBON DIOXIDE TREATMENTS GIVEN AT STORAGE TEMPERATURES ON SCALD, FLAVOR AND PROGRESS OF SOFTENING OF RHODE ISLAND GREENING APPLES, 1944–45.

Treatment Started	Length of Treatment (Days)	Carbon Dioxide Concentration (Per Cent)	Pressure Test Jan 29 (Pounds)	Scald Jan 29 (Per Cent)	Flavor Jan 29	Scald Feb 5 (Per Cent)	Flavor Feb 5
			Fruits Harvested Sep 1				
Check			11.62 ± 0.09*	20	Normal	78	Normal
Sep 2	3	30	13.62 ± 0.24	0	Normal	0	Normal
Sep 2	6	30	13.39 ± 0.16	0	Normal	0	Normal
Sep 2	10	30	14.30 ± 0.11	0	Normal	0	Normal
Sep 2	3	60	13.64 ± 0.18	0	Normal	0	Normal
Sep 2	6	60	14.66 ± 0.23	0	Normal	0	Normal
Sep 2	10	60	14.86 ± 0.21	0	Normal	0	Normal
Oct 5	3	30	13.44 ± 0.12	0	Normal	16	Normal
Oct 5	6	30	14.32 ± 0.19	4	Normal	6	Normal
Oct 5	10	30	13.68 ± 0.11	0	Normal	15	Normal
Oct 5	3	60	13.72 ± 0.15	10	Normal	20	Normal
Oct 5	6	60	13.10 ± 0.10	2	Normal	17	Normal
Oct 5	10	60	13.49 ± 0.13	3	Normal	24	Normal
			Fruits Harvested Sep 21				
Check			10.92 ± 0.12	5	Normal	50	Normal
Sep 22	3	30	11.86 ± 0.11	0	Normal	4	Normal
Sep 22	6	30	12.02 ± 0.11	0	Normal	6	Normal
Sep 22	10	30	12.10 ± 0.19	0	Normal	0	Normal
Sep 22	3	60	11.97 ± 0.21	0	Normal	10	Normal
Sep 22	6	60	11.67 ± 0.09	0	Normal	0	Normal
Sep 22	10	60	13.56 ± 0.31	0	Normal	0	Normal
Oct 23	3	30	11.32 ± 0.16	4	Normal	10	Normal
Oct 23	6	30	12.72 ± 0.16	0	Normal	14	Normal
Oct 23	10	30	12.33 ± 0.25	0	Normal	18	Normal
Oct 23	3	60	12.35 ± 0.25	0	Normal	6	Normal
Oct 23	6	60	12.36 ± 0.19	0	Normal	2	Normal
Oct 23	10	60	11.84 ± 0.30	0	Normal	6	Normal

*Standard deviation of the mean.

Samples of 12 fruits from each treatment were at that time subjected to pressure tests and examined for flavor, the remainder being left for a week at room temperature. Scald was noted at the time of taking the fruit out of storage, and then after 3 and 7 days at room temperature.

1943–44:—The apples were harvested on August 26, September 4, 14, 24, and October 4. Three two-kilogram samples of each picking were taken for determination of the respiration rate at 75 degrees F. The respiration rate was measured daily until the fruits were well past the climacteric stage.

TABLE II—THE EFFECT OF CARBON DIOXIDE TREATMENTS GIVEN AT 75 DEGREES F ON SCALD, FLAVOR AND PROGRESS OF SOFTENING OF RHODE ISLAND GREENING APPLES, 1944–45.

Treatment Started	Length of Treatment (Days)	Carbon Dioxide Concentration (Per Cent)	Pressure Test Jan 29 (Pounds)	Scald Jan 29 (Per Cent)	Flavor Jan 29	Scald Feb 5 (Per Cent)	Flavor Feb 5
Fruits Harvested Sep 1							
Check			11.62 ± 0.90*	20	Normal	78	Normal
Sep 2	1	30	12.92 ± 0.15	—	Normal	70	Normal
Sep 2	2	30	12.68 ± 0.17	10	Normal	60	Normal
Sep 2	3	30	12.78 ± 0.16	20	Normal	60	Normal
Sep 2	4	30	12.88 ± 0.18	48	Normal	75	Normal
Sep 2	1	60	12.64 ± 0.17	18	Normal	68	Normal
Sep 2	2	60	13.38 ± 0.18	0	Normal	15	Normal
Sep 2	3	60	13.06 ± 0.15	7	Normal	75	Normal
Sep 2	4	60	15.43 ± 0.31	0	Off	65	Off
Oct 5	1	30	13.44 ± 0.12	4	Normal	54	Normal
Oct 5	2	30	13.49 ± 0.13	20	Normal	52	Normal
Oct 5	3	30	13.66 ± 0.08	5	Normal	56	Normal
Oct 5	4	30	13.11 ± 0.18	10	Off	72	Off
Oct 5	1	60	13.25 ± 0.12	6	Normal	59	Normal
Oct 5	2	60	13.53 ± 0.28	20	Normal	55	Normal
Oct 5	3	60	14.20 ± 0.11	4	Off	54	Off
Oct 5	4	60	14.05 ± 0.12	0	Off	7	Off
Fruits Harvested Sep 21							
Check			10.92 ± 0.12	5	Normal	50	Normal
Sep 22	1	30	11.11 ± 0.09	12	Normal	45	Normal
Sep 22	2	30	10.69 ± 0.18	8	Normal	45	Normal
Sep 22	3	30	10.70 ± 0.10	4	Normal	35	Normal
Sep 22	4	30	11.75 ± 0.09	2	Off	25	Off
Sep 22	1	60	10.81 ± 0.15	0	Normal	28	Normal
Sep 22	2	60	10.92 ± 0.16	0	Normal	12	Normal
Sep 22	3	60	11.12 ± 0.22	0	Normal	5	Normal
Sep 22	4	60	12.64 ± 0.17	0	Normal	2	Normal
Oct 23	1	30	11.02 ± 0.23	0	Normal	20	Normal
Oct 23	2	30	10.86 ± 0.23	0	Normal	25	Normal
Oct 23	3	30	10.87 ± 0.09	0	Normal	33	Off
Oct 23	4	30	10.43 ± 0.23	0	Off	23	Off
Oct 23	1	60	12.20 ± 0.19	0	Normal	4	Normal
Oct 23	2	60	11.63 ± 0.20	0	Normal	46	Normal
Oct 23	3	60	11.94 ± 0.16	0	Normal	41	Normal
Oct 23	4	60	13.45 ± 0.27	0	Normal	20	Off

*Standard deviation of the mean.

Two bushel samples of each picking were given the following treatments:

(a) Immediate storage.
(b) 10- and 20-day delay in the boxes under the tree.
(c) 10- and 20-day delay, fruits spread on the ground under the tree.
(d) 10- and 20-day delay in the laboratory at 78 degrees F.

In addition, samples of each picking were packed in 5-gallon glass jars and sealed tight with screw tops and vaseline for 3, 7 and 10 days in the laboratory and for 10 and 20 days in the cold storage room. From 50 to 75 fruits, depending on size, were placed in each jar. Other samples were placed in similar jars and treated with ammonia and acetic acid for 3 and 4 days in the laboratory, and for 5 days in

TABLE III—THE EFFECT OF SEALING IN AIR-TIGHT JARS ON SCALD, FLAVOR AND PROGRESS OF SOFTENING OF RHODE ISLAND GREENING APPLES, 1944–45.

Treatment Started	Length of Treatment (Days)	Temperature (Degrees F)	Pressure Test Jan 29 (Pounds)	Scald Jan 29 (Per Cent)	Flavor Feb 5	Scald Feb 5 (Per Cent)	Flavor Feb 5
			Fruits Harvested Sep 1				
Check			11.62 0.09*	20	Normal	78	Normal
Sep 2	3	32	13.19 0.20	0	Normal	30	Normal
Sep 2	6	32	13.47 0.16	0	Normal	6	Normal
Sep 2	10	32	13.91 0.17	0	Normal	6	Normal
Sep 2	1	75	12.88 0.22	0	Normal	30	Normal
Sep 2	2	75	12.26 0.17	0	Normal	7	Normal
Sep 2	3	75	13.78 0.18	0	Normal	0	Normal
Sep 2	4	75	13.82 0.25	0	Off	0	Off
Oct 5	3	32	13.60 0.14	4	Normal	40	Normal
Oct 5	6	32	13.64 0.10	0	Normal	13	Normal
Oct 5	10	32	13.32 0.17	0	Normal	59	Normal
Oct 5	1	75	12 66 0.16	25	Normal	60	Normal
Oct 5	2	75	12.77 0.16	15	Normal	48	Normal
Oct 5	3	75	12.87 0.15	10	Normal	60	Normal
Oct 5	4	75	12.45 0.12	15	Off	25	Off
			Fruits Harvested Sep 21				
Check			10.92 0.12	5	Normal	50	Normal
Sep 22	3	32	11.59 0.12	0	Normal	18	Normal
Sep 22	6	32	11.64 0.11	0	Normal	0	Normal
Sep 22	10	32	12.37 0.22	0	Normal	4	Normal
Sep 22	1	75	10.89 0 18	3	Normal	40	Normal
Sep 22	2	75	10.32 0.08	7	Normal	60	Normal
Sep 22	3	75	10.82 0.07	0	Normal	53	Normal
Sep 22	4	75	11.64 0.12	0	Normal	0	Off
Oct 23	3	32	12.04 0.19	0	Normal	6	Normal
Oct 23	6	32	11.67 0.13	0	Normal	2	Normal
Oct 23	10	32	11.92 0.13	0	Normal	0	Normal
Oct 23	1	75	11.12 0.16	0	Normal	40	Normal
Oct 23	2	75	11.35 0.13	0	Normal	25	Normal
Oct 23	3	75	11.02 0.12	0	Normal	33	Normal
Oct 23	4	75	11.17 0.13	0	Off	25	Off

*Deviation of the mean.

the storage. At least one of these compounds is known to affect metabolism of apples (6). The concentrations of these vapors were not measured. Four and eight cc of commercial ammonia and glacial acetic acid were used per gallon of water through which the air was bubbled before passing through the jars.

1944–45:—Small samples of fruit were picked at weekly intervals throughout September to be used for respiration studies similar to those conducted during the 1943–44 season. The apples for scald control experiments were harvested on September 1 and 21, the latter date corresponding to recommended commercial harvest time. Some growers, however, pick their Greenings during the first half of September.

One-half the harvested fruits was treated immediately, the other half stored for a month at 32 degrees F and then subjected to the same treatments. The treatments of the past season consisting of sealing fruits in 5-gallon glass jars were repeated this year, but

the times of exposure were changed. Fruits were sealed for 1, 2, 3 and 4 days at room temperature, and for 3, 6 and 10 days at 32 degrees F. Most work, however, done during this season was concentrated on treating fruits with mixtures of air and carbon dioxide.

Two gas mixtures were used, one consisting of 30 per cent carbon dioxide and 70 per cent air, the other of 60 per cent carbon dioxide and 40 per cent air. These mixtures were prepared in 55 gallon steel drums. The drums were first filled with water, which was replaced by carbon dioxide from a tank commonly used in soda fountains, and then by air. The percentages of carbon dioxide in the mixtures were not constant or exact. The mixture designated as "30 per cent" contained between 20 and 40 per cent carbon dioxide, and the other designated as "60 per cent" fluctuated between 50 and 70 per cent as shown by actual determinations.

These mixtures of air and carbon dioxide were forced by means of water displacement to flow through rubber tubing into the above-described jars filled with fruits. This was accomplished by fitting two-hole rubber stoppers in the jar tops. The incoming air was conducted to the bottom of the jar by rubber tubing passing through one hole. The displaced air escaped through the other hole in the stopper. The rate of flow through each jar was from 2 to 10 liters per hour.

Oxygen concentration was not measured in the gas mixtures. It is believed, however, that the flow was fast enough to prevent any appreciable change of concentration of respiration process. It is assumed that the 30 per cent carbon dioxide mixture contained about 14 per cent oxygen and the 60 per cent carbon dioxide mixture about seven per cent oxygen.

Results

1943–44:—Respiration studies revealed that fruits picked on September 24 reached the climacteric peak on the third day when placed at 75 degrees F. Fruits harvested on October 4 were definitely postclimacteric.

The check fruits confirmed what has been known for a long time, that delayed picking reduces scald greatly. It was found, however, that even the fruits picked as late as October 4 had 20 per cent scald. Fruits picked in early September were all scalded. Fruits held before storage for 10 and 20 days in the orchard showed a little less scald than fruits stored immediately. Those kept at 78 degrees F for 10 and 20 days before storage were almost free of scald. They were, however, soft, yellow and showed lentical spotting similar to that described by Kidd and West (*7*), and their flavor was nauseating.

Ammonia and acetic acid vapors used in these experiments had no influence on scald. Fruits held in tightly sealed jars had no scald at all. Sealing for 7 and 10 days at room temperature and for 20 days in storage gave alcoholic flavors. Sealing for 3 days at room

temperature and for 10 days in storage had apparently no adverse effect on flavor. Treated apples were firmer than check fruits.

1944–45:—Respiration studies during this season have shown that the apples picked on September 21 reached their maximum respiration rate in 4 days after being placed at 75 degrees F, whereas fruits picked a week later were past the climacteric stage. The results obtained in scald control experiments during this storage season are shown in Tables I to III. It was found that fruits picked early developed more scald than those harvested 3 weeks later.

Sealing fruits in tight jars either at room or storage temperatures prevented scald when the treatments were given immediately after picking and carried on for a sufficient length of time. Delayed treatments were not as effective. Abnormal flavors resulted from most of four day treatments at room temperatures. Carbon dioxide treatments at room temperatures reduced the percentages of scald in all cases. The differences between particular treatments were inconsistent and erratic for which no explanation can be given at the present time. Whereas the percentage of scalded apples was decreased by carbon dioxide treatments at room temperature, its severity on individual fruits increased. Scalded areas on fruits thus treated were of darker brown color and deeper tissues were affected.

Carbon dioxide treatments given at storage temperatures appear very promising. Best results were obtained with fruits picked on September 1 and given immediate treatments. There was not a single scalded fruit in almost 400 apples exposed to 30 or 60 per cent carbon dioxide for 3, 6 and 10 days, while check fruits had 78 per cent scald (Table I).

Delayed carbon dioxide treatments given at storage temperatures to these early picked fruits were not as effective. In all cases, however, scald was reduced considerably and did not exceed 24 per cent in any treatment. Check fruits picked on September 21 had 50 per cent scald. Carbon dioxide treatments at storage temperatures gave good scald control. Immediate treatments seemed to be somewhat more effective than when delayed for one month. Maximum scald amounted to 10 per cent in the first, and to 18 per cent in the latter case.

Flavor was normal in all carbon dioxide treatments. Three fruits with an advanced stage of internal breakdown were found: one in September 1 fruits treated immediately with 60 per cent carbon dioxide for ten days, one in September 21 fruits treated after a month in storage with 30 per cent carbon dioxide for six days, and one in September 21 fruits treated after a month in storage with 60 per cent carbon dioxide for six days. In 2 bushels of check fruits picked on September 21, two apples were found affected with internal breakdown, and none in the same amount of check fruits picked on September 1. No internal browning or brown core was found in any case.

Ripening was delayed by all carbon dioxide treatments. The difference in pressure tests between check and treated fruits averaged between one and two pounds. This confirms Brooks' (3) findings on carbon dioxide treatments given to fruits directly after harvest.

Discussion and Conclusions

It has been known for a long time that some pre-storage treatments decrease susceptibility of fruits to scald. The mechanism of scald control thus obtained is not known. This is not surprising in view of the fact that the nature of the scald itself is not yet well known. Pre-storage pure nitrogen and pure carbon dioxide treatments for scald control used by Powell and Fulton (9) and by Brooks, Cooley and Fisher (1, 2) were not practical from the standpoint of storage operations. For the same reason, sealing fruits in jars is of only theoretical interest since such conditions could not be duplicated easily in storage. Treatments with carbon dioxide at room temperatures would be entirely possible. The results, however, obtained by this method were erratic and not consistent. More work will have to be done before any judgment can be made as to its practicability.

The group of treatments in which fruits were placed for a few days prior to storage in atmospheres of 30 to 60 per cent carbon dioxide at 32 degrees F deserves special consideration. The results thus obtained were very good and the conditions required for these treatments, it is believed, can be easily produced in commercial storages. Thirty per cent carbon dioxide gave very good scald control. U. S. D. A. workers (5) have shown that by using dry ice in transit of perishable fruits such atmospheres can be easily and quickly produced. The fact that wide variations in carbon dioxide content, 30 to 60 per cent or even wider as shown by our experiments, gave satisfactory results with no injury, is very important from the practical standpoint. Wide variations in the length of exposure (3 to 10 days) still enlarged the margin of safety. Flavor was not adversely affected in any of carbon dioxide treatments given at storage temperatures. The treated fruits were greener, crisper and firmer as shown by the pressure test.

No recommendations can be given on the basis of the above-described experiments. It will be necessary to determine if the same results can be obtained in the storage room with dry ice as a source of carbon dioxide. Concentrations and the length of exposure will have to be worked out in detail. The effect on other apple varieties, the limits of delayed and repeated treatments, and the effect of various concentrations of carbon dioxide on rodent control are some of the aspects of the problem which need further study.

Summary

Delayed storage by keeping fruits for 10 and 20 days at 78 degrees F prevented scald, but in most cases caused off-flavor in fruits. Ammonia and acetic acid vapors had no effect on scald when used during short pre-storage treatments. Sealing fruits in tight jars for a few days at storage and room temperatures prior to storage prevented scald in most cases if sufficient time of treatment was allowed. Pre-storage treatments with atmospheres of 30 and 60 per cent carbon dioxide at room temperature for 1 to 4 days gave some control of scald, but the results were erratic and not consistent. Pre-storage treatments with atmospheres of 30 and 60 per cent carbon dioxide at

storage temperatures for 3, 6 and 10 days gave very good scald control; no off-flavor was caused by the treatments and ripening was delayed.

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Changes in Reflectance of Flesh and Skin and in Composition of Maturing Transparent and Duchess Apples[1]

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TRANSPARENT and Duchess are the two most widely grown summer-ripening apple varieties in Illinois. A large part of the commercial crop is harvested in a somewhat immature condition. The work reported here was conducted to obtain information concerning the changes which occur during the maturation of the fruit, and the relation of these changes to edible quality which is recognized as being necessary for consumer acceptance. This is part of a general project on this subject.

MATERIALS AND METHODS

During the summer of 1944, spectrophotometric measurements of flesh and skin color changes of maturing fruits of these two varieties were made, using the methods and terminology previously described (4) and confining measurements to the outer cheek of the fruit. At each collection date about 50 fruits of average maturity of the tree as a whole were selected. Several typical fruits were used for spectrophotometric readings; and a comparable sample of 25 fruits used for the determination of fresh weight, transverse diameter, content of dextrose, levulose, sucrose, and starch, titratable acidity, and per cent of dry matter.

Determination of dry matter and subsequent preparation of the sample for analysis was carried out as previously described (2). Titratable acidity was determined on a 100-gram aliquot of the freshly cut-up material from which the aliquot for dry matter was also taken. This 100-gram sample was transferred to a Waring blendor, 300 ml. of water added and the material reduced to a homogeneous mass. It was then transferred to a 1000-ml wide-mouth Erlenmeyer flask and boiled 30 minutes, after which it was filtered through Whatman No. 4 filter paper in a Buchner funnel with moderate suction and the residue thoroughly washed to remove all traces of acid. The filtrate was transferred to a 1000 ml volumetric flask, cooled to room temperture, made to volume, and duplicate 50-ml aliquots taken for the determination of acidity by electrometric titration, using a Beckmann pH meter with glass electrode. Acid was then calculated as malic acid.

Sugars were determined by the method described by Lott (2) with the exception that the aliquot used for levulose and dextrose determinations was first decolorized with decolorizing carbon (Baker and Adamson, Code BA 1551), since it was found that pigments present in the sugar solution reacted with the iodine reagent and thus gave abnormally high dextrose values. This is in agreement with the results of Morris and Wesp (5). Starch was determined, on the residue from

[1]The author gratefully acknowledges the courtesy of J. O. Kraehenbuehl, Professor of Electrical Engineering, for making available and operating the Spectrophotometer for this work.

the sugar extraction, by the method of Heinze and Murneek (1). The result as dextrose was multiplied by 0.90 to correct for water taken up during the hydrolysis of starch to dextrose.

Both the Transparent and Duchess trees were 12 years old and were in a desirable state of vigor. They received an application of two and one-half pounds of ammonium nitrate per tree on November 1, 1943, and again on April 3, 1944. There was a full crop of fruit on all trees used. The Transparents were thinned on June 21 and the Duchess on June 30. To hold the fruits until they were fully mature, App-L-Set was applied at the rate of one-fourth pound to 100 gallons of water to the Transparents on July 10 and to the Duchess on July 19. It was very effective on the Transparents, very few fruits fell even when mature, and it was quite common for fruits to reach post-maturity, followed by cracking and falling away of the flesh, leaving the stem and core attached to the tree. It was less effective on Duchess but definitely beneficial. Effectiveness on Duchess may have been decreased by rain during the night following application of the spray.

The sampling dates reported here begin with each variety at a stage of maturity comparable to that at which commercial harvesting is begun in the early apple district of southern Illinois; namely, in Transparent when the fruits first reach a diameter of two inches, and in Duchess not later than July 4. Under these conditions, a large part of the crop of both varieties is harvested in an immature condition, the Transparents being definitely green in flesh and skin color, and the Duchess green in flesh and background skin color with the amount of red skin color varying from almost none to 25 to 35 per cent of the surface covered with light red stripes.

Transparent Results

Color.—The data in Table I were obtained from representative fruits at each of the picking dates indicated. Figs. 1 and 2 show the reflectance curves of flesh and skin of the same fruits. The 11 wavelength points shown in Table I are those at which reflectance maxima or minima occurred for one or more fruits, with the exception of the extremes of the chart at 400 and 700 mμ. The method of obtaining the A and B values is shown in Fig. 3.

Table I and Figs. 1 and 2 represent a range in maturity from definitely green and immature fruit on 7–7 to definite maturity on 8–4. The 8–4 fruits had what is frequently described visually as yellowish-white skin color and light creamy flesh, which became mealy after one or two days at room temperature. This is the ideal stage of maturity for home use and local or roadside markets. It is too soft for commercial shipment. The 7–28 fruits were considered at optimum maturity for commercial shipment but would probably become mealy before reaching the consumer when shipped long distances. In such cases a stage of maturity similar to the 7–21 sample should probably be used. These fruits were firm enough for all commercial purposes.

It can be seen from Table 1 and Figs. 1 and 2 that the Transparent curves were basically of the same type as those previously reported for yellow skinned varieties (3, 4). Fig. 1 shows that the outstanding

TABLE I—Reflectance Maxima and Minima for the Outside Cheek of Transparent Fruits of Average Color Development at Each Sample Date

Date Picked		Wavelength Points 1	2	3	4	5	6	7	8	9	10	11	A‡ Mμ	B§ (Per Cent)
							Flesh							
Jul 7	W*	400	*410*	*426*	434	*446*	468	478	*540*	550	676	700		
	R†	35.5	34.0	31.0	30.5	32.5	37.5	37.0	68.5	69.5	41.0	72 0	148	28.5
Jul 14	W	400	*410*	*422*	430	*448*	468	478	*540*	550	676	700		
	R	45.5	44.0	41.5	41.0	43.5	48.5	48 0	76 5	77.0	53.5	78.0	148	23.5
Jul 21	W	400	*410*	426	*440*	*444*	469	480	*538*	574	676	700		
	R	51.5	50.5	48.0	49.0	49.0	55.5	54.0	78.5	79.5	67.0	80.5	124	12.5
Jul 28	W	400	*410*	424	437	447	468	479	*536*	590	676	700		
	R	51.0	50.0	47.0	48.5	47.5	53.0	51.5	80.0	82.5	75.5	83 0	105	7.0
Aug 4	W	400	*410*	426	440	449	469	480	*540*	644	676	700		
	R	53.5	52.5	50.0	51 0	50.5	54.5	53.5	79.5	83.5	82.0	84.5	48	1.5
							Skin							
Jul 7	W	400	*410*	*422*	*434*	*448*	*470*	*478*	*540*	551	676	700		
	R	6.0	7.0	9.0	10.5	12.5	15.5	15.5	56.0	57.0	16.5	57.5	148	40.5
Jul 14	W	400	*410*	*422*	*434*	*448*	*462*	*478*	*540*	550	676	700		
	R	7.5	10.5	13.0	14 5	18.0	21 0	21.5	64.5	65.5	23.0	65.5	150	42.5
Jul 21	W	400	*412*	*426*	*434*	*448*	*466*	*476*	*538*	553	676	700		
	R	4.5	5.5	10.0	12.5	17.0	21.5	21.5	62.0	64.0	25.5	65.5	146	38.5
Jul 28	W	400	*410*	*422*	*434*	*450*	467	477	*540*	570	676	700		
	R	6.5	10.5	16.0	20.5	25.0	29.5	28.5	72.0	73.5	44.0	78.0	126	29.5
Aug 4	W	400	*410*	*426*	*438*	*446*	469	479	*538*	618	676	700		
	R	23.0	28 0	32.5	36.0	36.0	42 0	41.0	80.0	86.0	80.5	87.5	75	5.5

Italicized numbers indicate neither maximum nor minimum.
*Wavelength in millimicrons.
†Per cent reflectance.
‡Horizontal difference in millimicrons from point 9 to point of meeting curve beyond point 10.
§Vertical difference in per cent reflectance between points 9 and 10

TABLE II—Reflectance Maxima and Minima for the More Highly Colored Cheek of Duchess Fruits of Average Red Color Development at Each Sample Date

Date Picked		Wavelength Points 1	2	3	4	5	6	7	8	9	10	11	A‡ Mμ	B§ (Per Cent)
							Flesh							
Jul 14	W*	400	*410*	426	*436*	*445*	*470*	*478*	*540*	606	676	700		
	R†	27 5	26 5	25.5	26.0	27.5	32.5	32.5	59.0	63 0	49.5	74.0	84	13.5
Jul 21	W	400	*410*	*428*	*442*	448	470	480	*540*	636	676	700		
	R	44.0	42.0	38.5	38.5	38.0	42 5	41.5	69.0	74.0	66.0	79.5	54	8.0
Jul 28	W	400	*412*	425	435	447	468	478	*540*	638	676	700		
	R	49.0	48.0	46.0	46.5	46.0	50.0	49.0	74.5	79.0	75.0	81.5	51	4.0
Aug 4	W	400	406	430	438	452	*474*	*480*	*540*	660	676	700		
	R	43.5	44.0	42.0	42.5	42.0	44.0	44.0	72.5	82.0	81.8	83.0	24	0.2
							Skin							
Jul 14	W	400	*412*	*428*	*438*	*450*	466	480	*540*	609	676	700		
	R	4.5	5.0	7.5	9.0	10.5	11.5	11.0	20.5	35.0	16.5	55.0	82	18.5
Jul 21	W	400	*410*	*424*	*440*	*450*	466	484	*546*	633	676	700		
	R	4.5	4.5	6.0	8.0	9.0	10.0	9.5	13.5	39.0	20.0	60.0	58	20.0
Jul 28	W	400	*410*	*426*	*438*	*446*	466	489	*540*	637	676	700		
	R	4.0	4.0	5.5	6.5	7.0	8.0	7.0	7.2	48.0	28.5	71.0	52	19.5
Aug 4	W	400	*418*	*426*	*434*	*470*	*480*	484	540	*668*	*672*	700		
	R	4.5	4.5	5.0	5.5	6.0	6.0	5.7	5.4	62.5	62.5	76.5	0	0.0

Italicized numbers indicate neither maximum nor minimum.
*Wavelength in millimicrons.
†Per cent reflectance.
‡Horizontal difference in millimicrons from point 9 to point of meeting curve beyond point 10.
§Vertical difference in per cent reflectance between points 9 and 10.

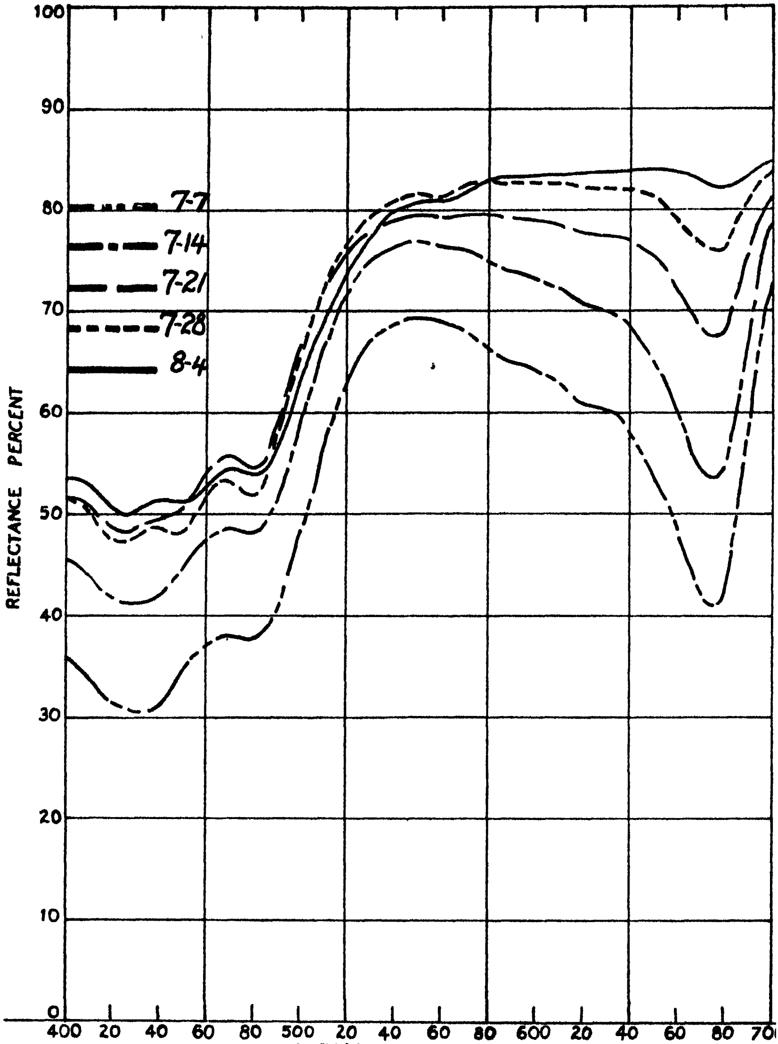

FIG. 1. Typical spectral reflectance curves from Transparent flesh at each sample date.

relationship between reflectance and flesh maturity occurred in the red part of the spectrum, particularly the reflectance at point 10 (676 mμ). The probable significance of the increased reflectance at this point as maturity progresses has been discussed previously (4). The shift of point 9 to a longer wavelength as well as greater reflectance should also be noted. These relations of points 9 and 10 to maturity are clearly evident in the A and B values shown in Table I. The low reflectance of the 7–7 sample in the violet and blue spectral regions (400–500 mμ)

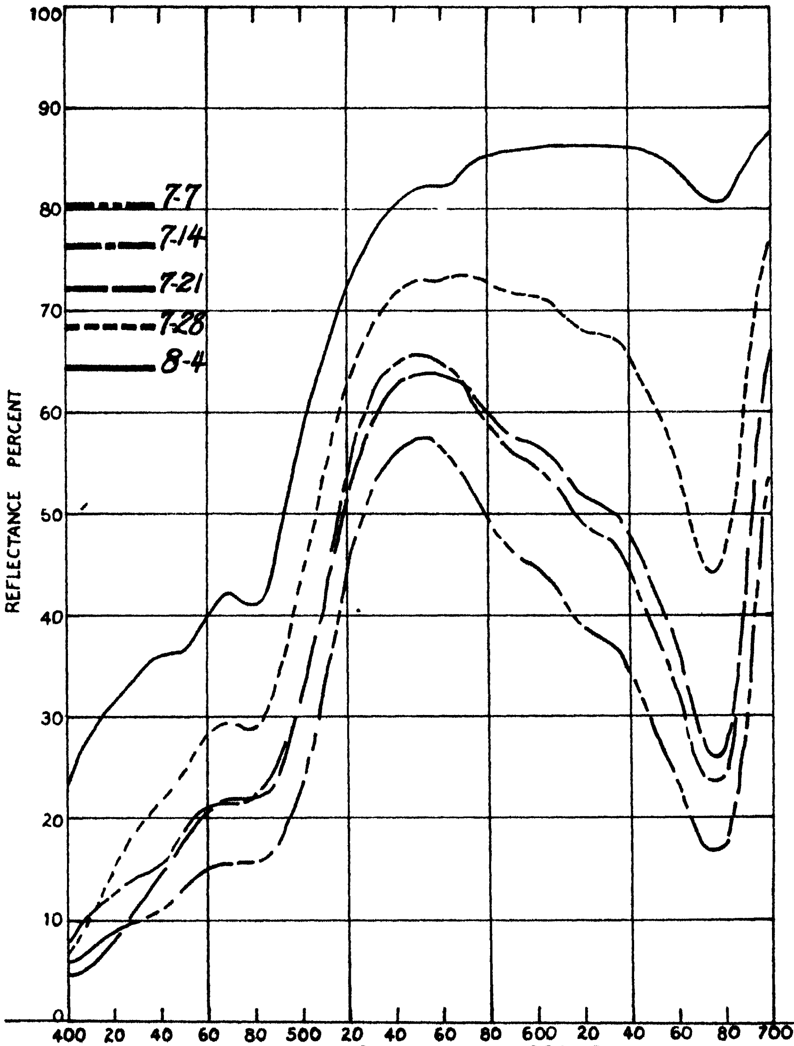

FIG. 2. Typical spectral reflectance curves from Transparent skin at each sample date.

should be noted, as well as the absence of a reflectance maximum in the vicinity of 447 mμ until the 7–28 sample. It may be concluded that there was a definite change in flesh color as maturity progressed. This was quite definite from wavelength 580 to 700 mμ.

Fig. 2 shows that at wavelength 676 mμ skin color behaved much as did flesh color, and presumably for the same reason. The definitely greater reflectance at all wavelengths of the 8–4 sample is plainly evident, as is also that of the 7–28 sample in comparison to earlier

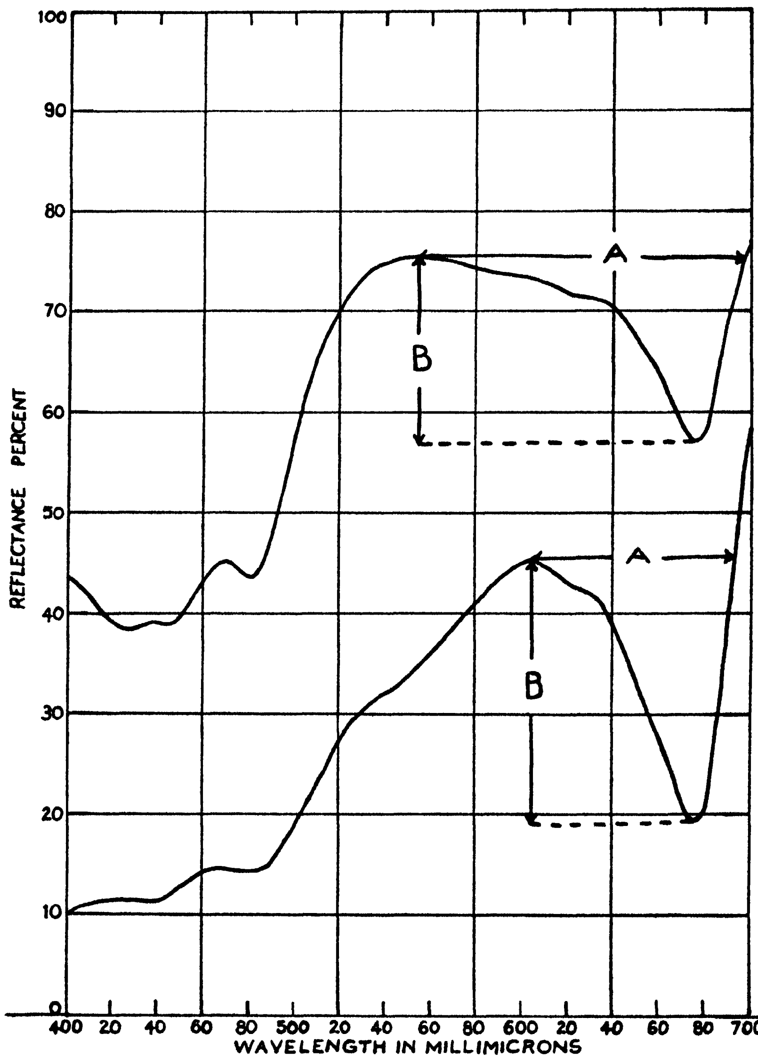

FIG. 3. Showing the method of determining the A and B values of flesh (above) and skin (below) spectral reflectance curves.

samples, with the exception of wavelengths 400 to 410 mμ. These definite differences in skin color at the desirable maturation stages in comparison to the earlier, greener stages shows the possibility of establishing maturity standards on the basis of color.

Size.—Table III shows that the transverse diameter of the fruit increased from 2.09 inches on 7–7 to 2.58 inches on 8–4. Corresponding increases in weight of fruit are evident. If the weight per fruit on 7–7 is taken as 100, the following relative weights are found at the

successive sample dates: 124, 151, 177, and 176. In other words, delaying harvest from 7–7 to 7–28, which was considered the stage of maturity best for commercial shipment except for extremely long distances, resulted in a 77 per cent increase in size. With the use of a hormone spray to prevent fruit drop, this is the equivalent of a 77 per cent increase in yield, a fact which merits more consideration by growers. The fact that the 8–4 sample was no larger than the 7–28 sample may have been due to sampling error, but is probably partly due to the initiation of senescence in these fruits shortly after the 7–28 sample. It was found that fruits that were still immature on 8–4 continued to increase in size and ultimately reached the 8–4 stage of maturity about 8–14. Such fruits should be left on the tree as long as possible to obtain the greater yield resulting from this continued size increase.

Composition.—Table III shows that sugars continued to increase, with the exception of dextrose and levulose in the 8–4 sample. The increase in the per cent of sucrose is particularly noticeable, although the increase in grams per fruit was practically the same as that of levulose. These sugar increases show that early harvesting of immature

TABLE III—COMPOSITION OF TRANSPARENT APPLE FLESH. URBANA, ILLINOIS, 1944

Date Collected	Grams Per Fruit	Per Cent of Fresh Weight							Grams Per Fruit					
		Dextrose	Levulose	Sucrose	Total Suggars	Starch	Acid	Dry matter	Dextrose	Levulose	Sucrose	Total Sugars	Starch	Acid
Jul 7	58.60	0.65	4.22	1.48	6.35	1.17	1.36	13.80	0.38	2.47	0.87	3.72	0.69	0.80
Jul 14	72.50	0.68	4.24	1.68	6.60	1.35	1.30	13.35	0.49	3.07	1.22	4.79	0.98	0.94
Jul 21	88.50	0.81	4.34	1.81	6.96	1.34	1.27	13.60	0.72	3.84	1.60	6.16	1.19	1.12
Jul 28	103.95	0.85	4.72	2.77	8.34	0.86	1.08	13.90	0.88	4.90	2.88	8.67	0.89	1.12
Aug 4	103.40	0.83	4.68	3.18	8.69	0.28	0.86	13.40	0.86	4.84	3.29	8.99	0.29	0.89

Diameters in order of collection dates—2.09, 2.23, 2.41, 2.56, 2.58 inches.

fruit inevitably results in low quality because of the relatively low sugar content at that time. The decrease in the per cent of acid while sugars were increasing further emphasizes the necessity for delayed harvest if quality is to be attained. This is also shown in the sugar-acid ratios in Table IV.

It can be seen in Table III that the per cent of starch was still

TABLE IV—RELATIVE PROPORTIONS OF THE DIFFERENT SUGARS AND THE RELATION OF EACH TO ACID. TRANSPARENT APPLE FLESH. URBANA, ILLINOIS, 1944

Date Collected	Per Cent of Total Sugars			Sugar/Acid Ratios			
	Dextrose	Levulose	Sucrose	Dextrose	Levulose	Sucrose	Total Sugars
Jul 7.......	10	66	23	0.48	3.09	1.09	4.65
Jul 14	10	64	25	0.52	3.27	1.30	5.10
Jul 21. . . .	12	62	26	0.64	3.43	1.43	5.50
Jul 28......	10	57	33	0.79	4.38	2.57	7.74
Aug 4......	10	54	37	0.97	5.44	3.70	10.10

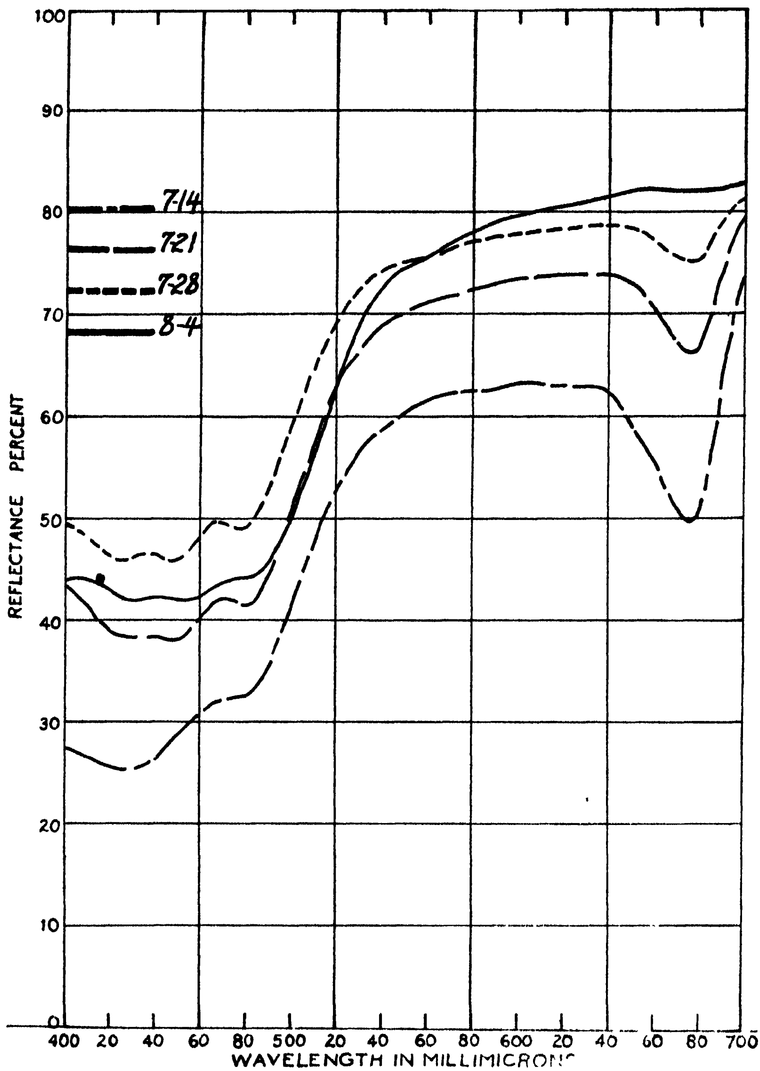

FIG. 4. Typical spectral reflectance curves from Duchess flesh on the cheek with the greater amount of red surface at each sample date.

increasing in the earliest pickings and did not show a significant decrease until the 7–28 sample when the fruit was approaching maturity.

It may be concluded that picking small, immature fruit results in a product low in sugar content, high in starch and acid, and inevitably low in quality. On the other hand, delaying harvest until the fruit is nearly mature results in an increase of sugars, particularly sucrose, and significant decreases in starch and acid, giving a higher sugar-acid

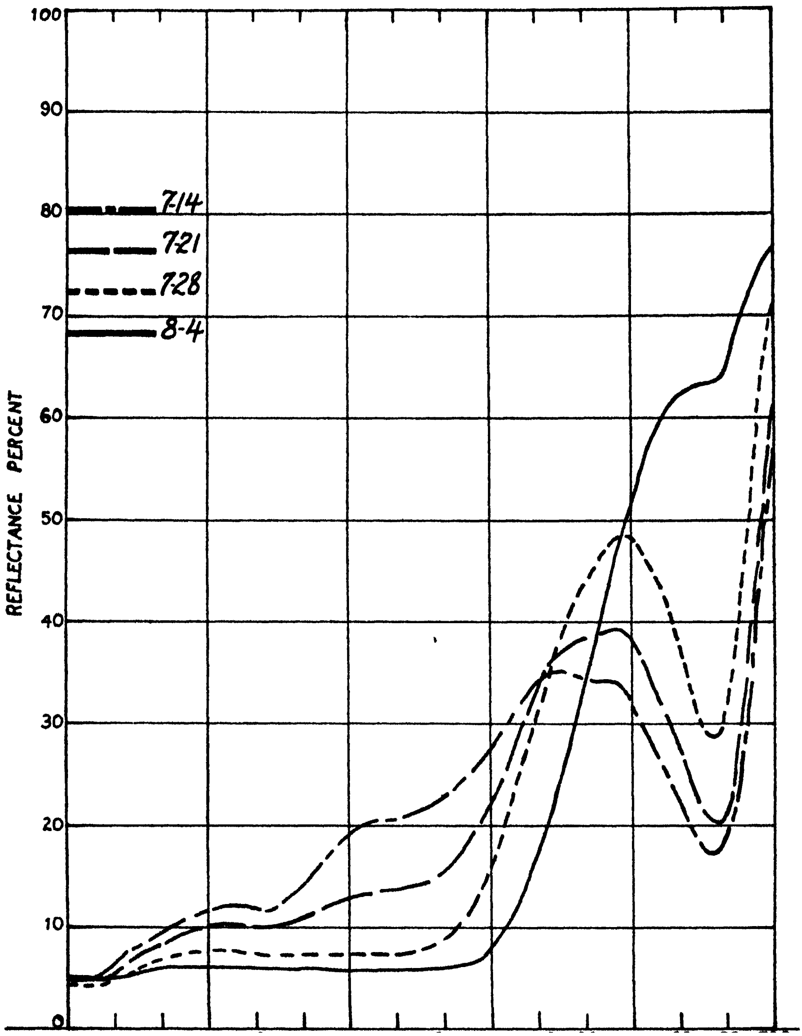

FIG. 5. Typical spectral reflectance curves from Duchess skin on the cheek with the greater amount of red surface at each sample date.

ratio and much higher quality than the earlier pickings. The quality increases are in addition to the very great size increases previously discussed.

Duchess Results

Color.—Figs. 4 and 5 show the reflectance curves of flesh and skin of the same fruits. In all samples the cheek with the greater amount of red color was used. In Fig. 4 are shown typical reflectance curves

of the flesh for the sample dates used. The general curve type was similar to that shown for Transparent in Fig. 1. Note the increased reflectance from wavelength 580 mμ to 700 mμ and at point 10 (676 mμ) as maturation progressed, the relatively low reflectance at all wavelengths of the green, immature 7–14 sample, and the decreasing A and B values shown in Table II.

The reflectance curves shown in Fig. 5 for the skin are typical of those previously reported for red-skinned varieties (3, 4). The 7–14 curve represents a green and red striped condition, with the per cent of the surface covered with red color increasing at each successive date up to the 8–4 sample when the background color was a red of medium value and high chroma overlaid with stripes of red of lower value but high chroma, giving the general effect of a bright, medium red. This brightness is typical of the high reflectance shown from wavelength 640 mμ to 700 mμ. The substitution of a shelf for a minimum at wavelength 676 mμ is noteworthy, since this is the first time such a condition was encountered. It has since occurred several times in measuring reflectance of peaches and has also been found in the case of stored apples. As shown in Fig. 5, the color characteristics of the skin of maturing Duchess apples were found to be a decreasing reflectance between wavelengths 400 mμ and 600 mμ and an increasing reflectance between wavelengths 640 mμ and 700 mμ. This has also been found to be typical of other red-skinned varieties (3, 4). It should be borne in mind, however, that under environmental conditions which inhibit maximum color development the reflectance at maturity will likely be more nearly like that shown for the 7–14 sample.

Size.—As was the case with Transparent, there was a marked increase in transverse diameter and in fruit weight at each successive sample date, Table V. The diameter increased from 2.33 inches on 7–14 to 2.76 on 8–4. The relative weights per fruit on the basis of the 7–14 sample as 100 were 121, 140, and 171. These show the great effect on yield of allowing the fruits to reach maturity before harvest.

Composition.—It is evident in Table V that there was an increase in each of the three kinds of sugar at each successive sample date. This

TABLE V—Composition of Duchess Apple Flesh. Urbana, Illinois, 1944

Date Collected	Grams Per Fruit	Per Cent of Fresh Weight							Grams Per Fruit					
		Dextrose	Levulose	Sucrose	Total Suggars	Starch	Acid	Dry matter	Dextrose	Levulose	Sucrose	Total Sugars	Starch	Acid
Jul 14	77 20	0.72	4.60	1.20	6.61	1.38	1.33	13.75	0.56	3.62	0.93	5.10	1.07	1.03
Jul 21	92.80	0.73	5.02	1.26	7.01	1.53	1.24	13.95	0.68	4.66	1.17	6.51	1.42	1.15
Jul 28	108.00	0.78	5.16	1.35	7.30	1.11	1.10	13.90	0.84	5.57	1.46	7.88	1.20	1.19
Aug 4	132.15	0.97	5.69	2.96	9.63	0.60	0.81	14.85	1.28	7.52	3.91	12.73	0.79	1.07

Diameters in order of collection dates—2.33, 2.48, 2.61, 2.76 inches.

is particularly noticeable in the per cent of sucrose, but there was a greater increase in the amount of levulose per fruit from the first to the last sample than in sucrose. However, when the last two samples are compared, it is found that the increase in amount per fruit was

greater in sucrose than in levulose. There was, then, in both Duchess and Transparent, a rapid influx of sucrose just before maturity was reached.

The behavior of starch in Duchess was very similar to that in Transparent, with an increase during the first week, followed by a decrease, with the greatest decrease coming just before maturity. It should be noted that the decrease in amount of starch per fruit was not great enough in either variety to offset the increase in the amount of sugars per fruit. The difference is particularly noticeable in Duchess. It is evident, then, that as the fruit matured the increase in amount of sugar per fruit came primarily from the photosynthetic activity of the leaves and carbohydrates stored in the tree, and secondarily from the hydrolysis of starch in the fruit. The carbohydrates lost by respiration would have to be included in a complete analysis of this question. The extend of this respiration loss is unknown, but it may be considerable at the temperatures which prevail in this region in July and early August.

Just as in Transparent, the per cent of acid decreased as the season progressed; the amount per fruit increased until the fruit was nearly mature and decreased in the last sample. This decrease in amount of acid per fruit coincided with a rapid rise in sucrose. This is shown in both Tables IV and VI in the relative proportions of the different sugars and in the sugar-acid ratios.

TABLE VI—Relative Proportion of the Different Sugars and the Relation of Each to Acid. Duchess Apple Flesh. Urbana, Illinois, 1944

Date Collected	Per Cent of Total Sugars			Sugar/Acid Ratios			
	Dextrose	Levulose	Sucrose	Dextrose	Levulose	Sucrose	Total Sugars
Jul 14 . . .	11	71	18	0.54	3.51	0.90	4.95
Jul 21 . . .	10	72	18	0.59	4.05	1.02	5.66
Jul 28 . . .	11	71	19	0.71	4.68	1.23	6.62
Aug 4 . . .	10	59	31	1.20	7.03	3.65	11.90

Summary and Conclusions

A study of spectral reflectance of maturing Transparent and Duchess apples showed an increase in reflectance from Transparent flesh and skin and from Duchess flesh between wavelengths 580 mμ and 700 mμ as maturation progressed, and in Duchess skin a decrease in reflectance between wavelengths 400 mμ and 600 mμ and an increase in reflectance between wavelengths 640 mμ and 700 mμ as the fruit matured. The differences were great enough between samples to indicate the possibility of establishing maturity standards on the basis of color.

Examination of samples comparable to those used for spectrophotometric determination showed that the following were characteristic of both varieties as the fruit approached maturity; a rapid increase in size and weight; an increase in dextrose, levulose and sucrose, with a particularly marked increase in sucrose as maturity was reached; an initial increase in starch content, followed by a decrease most pro-

nounced in the week preceding maturity; a decrease in the per cent of acid in each successive sample but an increase in the amount per fruit until just before maturity, when a decrease occurred; and in the sugar-acid ratio a continuous increase which was most pronounced as maturity was reached.

These data show the need for more comprehensive grades in these two varieties. Under U. S. No. 1 grade requirements all of the samples reported here would be marketed as U. S. No. 1; in fact, they represent the range in maturity commonly marketed under this grade in Illinois, with most of the fruit represented by the immature samples. It is obvious that the much higher quality fruit represented by the later samples can be made available to the consumer only by the use of more selective, less general grade requirements based on the principle of grading according to quality. The possibility of using spectrophotometric information for maturity determinations during the picking and packing of apples has been discussed previously (4).

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Cold Storage Studies with Minnesota-Grown Apples[1]

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THE studies were made with apples packed in half-bushel baskets and placed in commercial cold storage at 31 to 32 degrees F. The fruit was grown in various orchards in central and southeastern Minnesota and it was placed in cold storage soon after picking. A standard Ballauf fruit pressure tester was used to determine pressures at time of storage and when lots were withdrawn for examination by staff members of the Division of Horticulture.

No lot that showed an unusually low pressure test for the variety at time of storage appears in the summary of data, and this summary includes only well matured fruit, free from apparent skin punctures at time of storage. In most instances, each apple was wrapped in standard oiled tissue paper, although some unwrapped lots were stored.

A summary of the storage records for the years 1941 to 1944, inclusive, is given in Table I. The data for wrapped and unwrapped lots are not given separately as no consistent differences were found. Pressure tests did not accurately indicate the condition of the fruit toward the end of the storage season. For example, in one season the Cortland was in good condition at 12.5 pounds, but in another season it was not in good condition at 14.5 pounds. In general, most varieties tested approximately 12 to 14 pounds at the end of their storage season.

Soft Scald at 31 to 32 Degrees F:—Relatively little soft scald was found during the first 30 to 60 days in storage. Severe scald developed

TABLE I—SUMMARY OF STORAGE TESTS OF 15 VARIETIES OF APPLES HELD AT 31 TO 32 DEGREES F

Variety	Crops Stored (Years)	Approximate Pressure Test When Stored (Pounds)	End of Normal Storage Period in Good Condition (Approximate Date)	Rots and Scalds	
				2 to 4 Months (Per Cent)	4 to 6 Months (Per Cent)
Cortland	1	26	Jan 15	0.0	—
McIntosh	1	21	Jan 15	0.0	—
Minjon	3	19	Jan 15	2.7	—
Minnesota No. 724**	3	19	Jan 15	0.0	—
Minnesota No. 978**	2	22	Jan 15	1.3	—
Wealthy	2	19	Jan 15	8.7	—
Minnesota No 790	3	30	Mar 1	0.0*	3.5*
Victory	3	29	Mar 1	0.6	2.6
Fireside	3	29	April 1 to May 1	0.6	0.7
Haralson	4	29	April 1 to May 1	2.5	3.6
Minnesota No. 638	2	28	Storage unsatisfactory	15.8	—
Minnesota No. 643	1	17	Storage unsatisfactory	41.8	—
Northwestern	1	31	Storage unsatisfactory	37.4	43.2
Prairie Spy	3	30	Storage unsatisfactory	31.9	33.0
Wedge	3	19	Storage unsatisfactory	54.3	—

*Some defects from growth cracks in stem cavity are not included.

**Storage period possibly longer than shown. All lots were in good condition about January 15 and no examinations were made in February.

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during December and January on the five varieties shown in Table II. The data shown in the 1-year test with Northwestern may not be considered typical, although this is the most susceptible of commonly grown midwestern varieties to soft scald injury.

Scald, averaging 33 per cent, was found on Minnesota No. 638 in 2 additional years not included in Table II because the fruit was soft when stored. Severe scald developed in a 1-season test with less than half-bushel lots of Blue Permain No. 1, Minnesota No. 671, and Minnesota No. 793, not shown in Table II. Scald also developed in 1 season on one lot each of Fireside, Minjon, Minnesota No. 724, Minnesota No. 838, and Wealthy that had been picked in an immature condition and were delayed before entering storage. No scald developed at any time on Cortland, Haralson, McIntosh, Minnesota No. 790, Minnesota No. 978, and Victory.

TABLE II—DEVELOPMENT OF SOFT SCALD ON APPLES HELD AT 31 TO 32 DEGREES F

Variety	Crops Stored (Years)	Scald Found (Years)	Average Scald After 2 to 6 Months (Per Cent)
Wedge	3	3	53.8
Minnesota No. 643	1	1	39.7
Northwestern	1	1	37.4
Prairie Spy	3	3	30.5
Minnesota No. 638	2	2	14.4

Storage at 42 Degrees F:—It is known that storage at 36 degrees or higher usually prevents injury from soft scald. A preliminary test was made with Prairie Spy from the 1944 crop stored at approximately 42 degrees. No scald and no rots were found on January 23, and no scald but 12 per cent rots were found on March 24, 1945. The apples, except for the rots, were in very good condition up to March 24. It is probable that a temperature of 36 degrees, which was not available, would have materially reduced the development of rots.

SUMMARY

In cold storage studies with Minnesota grown apples held at 31 to 32 degrees F the varieties Cortland, McIntosh, Minjon, Minnesota No. 724, Minnesota No. 978, and Wealthy were held in good condition until approximately January 15; Minnesota No. 790 and Victory were held until about March 1; and Fireside and Haralson were held until April 1 to May 1. The storage of Prairie Spy, Minnesota No. 643, Minnesota No. 638, Northwestern, and Wedge was unsatisfactory because of soft scald. Preliminary investigations with Prairie Spy indicated that soft scald could be prevented by storage at a higher temperature.

Variations in Size and Composition of Yellow Transparent Apples Packed as Ill.-U.S. No. 1

By Richard V. Lott and Dillon S. Brown, *University of Illinois, Urbana, Ill.*

In Illinois, the commercial production of the Yellow Transparent apple is most extensive in Johnson and Union counties in the Ozark section in the southern part of the state. For many years, it has been the prevailing practice to begin harvesting the crop when the largest fruits become two inches in diameter. This practice has been the result of a desire on the part of growers to market their fruit at the relatively high price prevailing at that time, despite the fact that it has been shown that very significant increases in yield and quality would be obtained by allowing the fruit to become more nearly mature before harvest (1, 3). Growers have hesitated to delay harvest because the price has usually declined so rapidly after the first week or 10 days following the beginning of harvest that they have not thought that the increased yield gained by delaying would offset the price decline.

It has seemed possible, if not probable, that the decline in price as the season advanced has not been due primarily to an oversupply of fruit, but rather to the immature, low-quality condition of the first shipments, which has resulted in low consumer acceptance and falling prices. Consequently, it seemed desirable to make some determinations of the variation in the size and quality of the Yellow Transparent apples being packed in Illinois so as to have definite information available on the characteristics of the product being offered to the consumer.

Materials and Methods

For the purposes of this investigation, packed bushel baskets of fruit were taken at random at the packing sheds during the 1944 harvest season. Bushels 1, 2, and 3 came from Johnson County, and 4 and 5 from Union County. Bushels 1 and 3 came from the same grower but at different dates, as shown in the footnote to Table III. They were all packed as Ill.-U. S. No. 1, two-inch minimum. The fruit was brought to Urbana and unpacked, keeping the facers separate from the remainder of the bushel. The weight in grams and the diameter in inches was determined for each fruit. The fruits were then separated on the basis of degree of maturation (Table III), and a 25-fruit sample used for the chemical determinations. Sugars, starch, acidity, and dry matter were determined by the methods previously described (3).

Results

Size:—Table I shows the average size of fruits in weight and in diameter for the whole bushel and for the facers alone. There seems to be a quite common idea among consumers that the largest apples are nearly always used for facers. Table I shows that, in each bushel, the average weight per fruit of the facers was greater than that of the

TABLE I—AVERAGE WEIGHT AND DIAMETER PER FRUIT AND COEFFICIENTS OF VARIABILITY IN YELLOW TRANSPARENT APPLES PACKED AS ILL.-U. S. No. 1, 1944

Bushel Number*	Weight in Grams		Diameter in Inches		Weight		Diameter	
	Mean	S E.**	Mean	S.E.	C.V.***	S E.	C.V.	S.E.
1 C	64.72	0.929	2.193	0.0096	25 76	1.077	7.88	0.311
F	90.98	1.819	2.466	0.0181	13.15	1.426	4.88	0.520
2 C	76 48	1 047	2.345	0.0120	21.90	1.013	8 20	0.362
F	87 55	2 911	2 462	0 0319	23.27	2.475	9.08	0.917
3 C	60.40	0.547	2.169	0.0069	16.24	0.841	5.71	0.225
F	62.91	1.228	2.198	0.0161	14.86	1.410	5.59	0 519
4 C	67.83	0.854	2.281	0.0107	21.28	0.971	7.92	0.331
F	78.31	1.297	2.406	0.0186	11 59	1 186	5.41	0.547
5 C	73.32	0.951	2.311	0 0116	21.70	0 959	8.42	0.356
F	91.26	1.841	2.516	0.0213	13.68	1.453	5.73	0.597

*C—complete bushel, F—facers.
**Standard error.
***Coefficient of variability.

whole bushel. This difference was statistically significant in all but Bushel 3. Bushel 1 was obviously greatly overfaced.

In considering size of individual fruits on the diameter basis, it is again seen in Table I that in each bushel the facers were larger than the fruits in the bushel as a whole. This difference was statistically significant in all but Bushel 3. Four of the five bushels were overfaced from the standpoint of both weight and diameter. Lack of personnel prevented the examination of a large number of bushels, but from the five bushels that were examined it is evident that overfacing does occur. From the standpoint of the consumer, it is quite doubtful that it should ever occur.

Table I also shows that the coefficient of variability, as to both weight and diameter, was significantly greater in the whole bushels than in the facers in Bushels 1, 4, and 5.

In considering the difference between bushels, it was found that each bushel was significantly different from each of the others in average weight and size of apples, with the exception that the fruits in Bushels 4 and 5 were not significantly different in diameter. It is obvious then, that U. S. No. 1 grade laws permit not only overfacing of apples packed in bushel baskets, but also considerable variation between baskets, thus subjecting the consumer to a very variable product. This is particularly brought out in the difference in weight shown in Table I between the facers and the whole bushel in every case and between whole Bushels 2 and 3.

Table II shows that in each bushel there was a range in diameter from less than two inches to over two and one-half inches. There was also a wide difference in diameter between bushels, as shown by Bushel 2 with only 256 apples, as compared to Bushels 1 and 3 with 322 each or 25.8 per cent more. The weight per fruit distribution further shows the wide variation found in each bushel, with a range from under 50 grams to over 100 grams in each bushel. In one bushel, the range in weight per fruit was from 39 grams to 167 grams, a

difference of 328 per cent; in other words, the largest fruit was 4.28 times as heavy as the smallest. It seems quite probable that such variability in size as shown in Tables I and II is a serious deterrent to consumer acceptance of Yellow Transparent apples.

TABLE II—DISTRIBUTION OF YELLOW TRANSPARENT APPLES IN SIZE CLASSES AS PER CENT OF TOTAL IN BUSHELS, 1944

Bushel Number	*Diameter in Inches*						
	1.75 2.00	2.00–2.25	2.25-2.50	2.50–2.75	2.75 3.00	3.00–3.25	Total Number Apples
1	6.5	67.2	18.9	7.5	—	—	322
2	2.3	25.8	56.7	12.5	2.3	0 4	256
3	3.7	76.2	18.9	1.2	—	—	322
4	1.7	45.8	42.0	9 5	1.0	—	286
5	2 1	37.6	46 8	11.0	2.5	—	280

Bushel Number	*Weight in Grams*									
	Under 50	50-60	60–70	70 80	80-90	90–100	100–110	110-120	120-130	Over 130
1	9.6	43.8	19 9	9.6	7.8	3.1	5.0	0 3	0 9	—
2	3.1	9.8	24.2	26.1	21.5	6.6	4.3	2.7	1.2	0.4
3	8 7	46.3	32 6	9.0	1.9	0.9	0.6	—	—	—
4	6.3	28.3	25 9	21.3	10.8	4.6	1.4	1.4	—	—
5	3 6	13.9	32.9	22.8	13.2	6.4	3 2	2.5	0.4	1.1

Composition:—Table III shows that in each bushel the fruit selected as more nearly mature had a higher percentage of levulose, reducing sugars, sucrose, and total sugars than those of lesser maturation. While the differences are small in some cases, the trend is, nevertheless, definite. Since sugars make up the greater part of the dry matter of apple fruits, it seems desirable to consider the relation of the sugar content to stage of maturation and consequent quality. It is evident that the M-1 samples of Bushels 1 and 2 were quite definitely lower in sugar content than the more nearly mature

TABLE III—SUGARS, STARCH, ACID, AND DRY MATTER AS PER CENT FRESH WEIGHT IN YELLOW TRANSPARENT APPLES PACKED AS ILL.-U. S. NO. 1, 1944

Bushel Number	Maturation*	Reducing Sugars			Sucrose	Total Sugars	Starch	Acid†	Dry Matter
		Dextrose	Levulose	Total					
1**	M-1	1.07	3.93	4.99	1.43	6.42	1.27	1.43	13.60
	M-2	0.96	4.23	5.19	1.48	6.77	1.39	1.46	14.70
2	M-1	1.15	3.93	5.08	1.10	6.18	0.99	1.32	13.15
	M-2	1.01	4.61	5.62	1.57	7.19	1.18	1.38	14.25
3	M-2	1.23	4.71	5.95	1 41	7.36	0.96	1.18	14.20
	M-3	1.21	5.24	6.45	1.60	8.04	0.91	1.12	14.70
4	M-2	0.94	4.62	5.56	1.08	6.65	1.09	1.23	13.33
	M-3	0.97	4.80	5.77	1.41	7.18	1.19	1.18	13.68
5	M-2	0.88	4.42	5.30	1.56	6.86	1.23	1.33	13.38
	M-3	0.95	5.08	6.03	1.81	7.84	0.98	1.21	13.93

*M-1, M-2, M-3, increasing degrees of maturation.
**Bushels 1 and 2 picked and packed 6–21–44; 3, 4 and 5, 6–30–44.
†As malic.

fruits in the same basket and lower than both the M-2 and M-3 fruits in the later picking. These data again emphasize the great variability in fruit which meets the requirements of the Ill.-U. S. No. 1 grade; the M-3 sample of Bushel 3 had 30 per cent more total sugar than the M-1 sample of Bushel 2. Considering the fact that Yellow Transparent apples usually fail to attain the sugar content of later varieties (1, 2), and that sugar content is associated with quality in apples, it is evident that the M-1 samples of Bushels 1 and 2 were of low quality as compared to the more nearly mature fruits in bushels 3, 4, and 5.

The data of Table III show that even the most nearly mature fruits were low in total sugar content in comparison with mature Yellow Transparent apples which had percentages of 8.60 (1) and 8.69 (3). This indicates that all of the fruits in each bushel were immature, even though separation on the basis of degrees of maturation was possible. This immaturity is further emphasized by the relatively high acid values of nearly all samples, only the M-3 sample of Bushel 3 having an acid concentration approaching that usually found in mature Yellow Transparent apples. During three other seasons, the mature fruit of Yellow Transparent grown in southern Illinois had an acid content of 1.00 per cent of less.

Conclusions

The results, although obtained from a relatively small number of bushels in only one season, bring out definitely some undesirable aspects of the present practices in the harvesting and marketing of Yellow Transparent apples in southern Illinois. It is apparent that the pack now in use, namely, Ill.-U. S. No. 1, makes possible wide variability in size and composition within individual bushels and between bushels. Under this grade, the whole crop could legally be picked and packed in a very immature condition; in fact, most of the crop is harvested in a condition of variable immaturity, with but little if any of it left on the trees to reach maturity.

Putting this immature, low-quality fruit on the retail market undoubtedly results in greatly reduced consumer acceptance and a reduction in price and consequent returns to the industry. It seems that the consumer acceptance necessary to the continuance of the industry can be greatly increased by picking only mature fruit and the adoption of packing requirements that can be enforced to insure a product relatively uniform in size and quality.

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The Use of Decolorizing Carbon to Avoid Error in the Determination of Dextrose in Fruits by the Lothrop and Holmes Method

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DURING investigations concerning the development, maturation, or ripening of fruits it is frequently desirable to determine the relative quantities of dextrose, levulose, and sucrose present. Because of the large number of samples frequently involved it is desirable to use methods which are relatively simple, rapid, and within the desired limits of accuracy. Methods for the determination of sucrose and reducing sugars in fruit tissues are well established by usage. However, methods for the differentiation of the reducing sugars as dextrose and levulose have not been so well established. The Lothrop and Holmes method (3) has been used for this purpose by Gerhardt and Ezell (2) with pears, by Mohamed and Mrak (6) with figs, and with modifications by Martin (5) with pears, and by Lott (4) with apples.

The method consists essentially in the oxidation of dextrose in alkaline solution with N/20 iodine, acidification to release the iodine from any sodium iodate formed when the NaOH is added to make the solution alkaline, and titrating the excess iodine with N/20 sodium thiosulfate. The weight of dextrose oxidized by the iodine is calculated on the basis that 1 ml. N/20 iodine solution oxidizes 0.0045 grams dextrose. From this value and the previously determined percentage of reducing sugars the true percentages of dextrose and levulose are calculated by the formula given by Lothrop and Holmes which takes into account the slight oxidation of levulose by the iodine. The method is simple, rapid, and well within the limits of accuracy desired with fruit samples if the precaution mentioned by Bates (1) is taken into consideration. The suggestion of Martin (5) that the quantity of reagents be halved, because of the relatively low dextrose values in fruit tissues, saves time and reagents.

The author used this method in determining the dextrose and levulose content of the mature fruits of fifteen apple varieties (4). Later, in following the dextrose-levulose relationship in fruit samples from bloom to maturity, it was found that the extracted sugar solution contained material which was oxidized by iodine, thus introducing an error. Since that time the method of Morris and Wesp (7) has been followed for the removal of the pigmented material which is oxidized by the iodine. This material has been removed by adding one gram of decolorizing carbon (Baker and Adamson, Code BA 1551, as used by Morris and Wesp) to a one-fifth aliquot (50 ml) of the sugar solution, mixing well and allowing to stand for about 10 minutes, followed by filtering and thorough washing of the residue. The use of the carbon with samples of pure dextrose solution showed that the carbon did not retain any of the dextrose, which is in agreement with the report of Morris and Wesp (7). It was also found that the use of the carbon in mixtures of pure solutions of dextrose, levulose, and sucrose in the approximate proportions in which these sugars occur

in apple and peach fruits did not result in the retention of any of the dextrose.

Table I shows the effect of the use of the carbon upon the per cent of dextrose in apple and peach samples. The apple samples extend from bloom or shortly thereafter to maturity in each variety. The peach samples for each year represent picking at three degrees of maturation, followed by ripening at room temperature (approximately 85 degrees F) for 3 and 6 days, as indicated. The first sample in each case was taken the day following picking. The details of the investigation of which these peach samples form a part will be published elsewhere.

TABLE I—THE EFFECT OF DECOLORIZING THE SAMPLE SOLUTION IN THE DETERMINATION OF DEXTROSE IN APPLES AND PEACHES

Sample Date	Dextrose* (Per Cent) +C**	Dextrose* (Per Cent) -C†
Jonathan—1942		
May 8	0.42	2.32
May 22	0.57	1.76
Jun 1	0.58	1.58
Jun 16	1.09	1.55
Jun 30	1.24	1.92
Jul 15	1.05	1.56
Jul 27	1.05	1.50
Aug 3	0.94	1.25
Aug 10	0.90	1.49
Aug 25	1.09	1.46
Sep 1	1.44	1.77
Sep 10	1.79	2.22
Sep 14	1.90	2.21
Sep 21	1.77	2.06
Sep 28	1.85	2.15
Oct 5	1.95	2.20
Golden Delicious—1942		
May 4	0.34	2.30
May 11	0.51	2.74
May 19	0.56	2.11
Jun 1	1.15	2.37
Jun 9	1.24	2.25
Jun 23	1.48	2.20
Jul 6	1.59	2.13
Jul 20	1.40	1.72
Aug 3	1.38	1.72
Aug 10	1.32	1.88
Aug 25	1.37	1.69
Sep 1	1.49	1.82
Sep 10	1.43	1.67
Sep 15	1.69	1.98
Sep 24	1.50	1.78
Oct 1	1.57	1.83
Oct 8	1.61	1.88
Yellow Transparent—1942		
Apr 28	1.13	2.55
May 5	0.59	1.33
May 12	0.50	1.78
May 20	0.70	2.14
May 26	0.75	2.33
Jun 2	0.83	2.19
Jun 9	0.87	1.94
Jun 16	0.93	1.73
Jun 23	1.03	1.90
Jun 30	0.94	1.76
Jul 6	0.90	1.39
Jul 14	0.88	1.43
Jul 21	0.87	1.14
Jul 28	0.82	1.11
Elberta—1943		
Aug 17, M-1††	1.22	1.66
Aug 20, M-1	1.28	1.74
Aug 23, M-1	1.47	1.80
Aug 17, M-2	1.43	1.94
Aug 20, M-2	1.52	2.05
Aug 23, M-2	1.57	1.85
Aug 17, M-3	1.57	2.07
Aug 20, M-3	1.80	2.19
Aug 23, M-3	1.63	1.99
Elberta—1944		
Aug 15, M-1	1.30	1.62
Aug 18, M-1	1.43	1.83
Aug 21, M-1	1.50	1.91
Aug 15, M-2	1.27	1.55
Aug 18, M-2	1.54	1.86
Aug 21, M-2	1.54	1.90
Aug 15, M-3	1.41	1.72
Aug 18, M-3	1.51	1.87
Aug 21, M-3	1.59	2.02

*As per cent of fresh weight.
**Decolorizing carbon added.
†Decolorizing carbon not added.
††M-1, M-2, M-3 = increasing degrees of maturation.
Full bloom = Jonathan, April 28; Golden Delicious, April 29; Yellow Transparent, April 28.

The table shows that at each sample date the dextrose value was erroneously high in the undecolorized sample, as a result of the oxidation of the pigment by the iodine. Note that this error was much greater in the apple samples taken early in the season than in those at or near maturity, although it was quite significant in the latter samples.

On the basis of these results the dextrose and levulose values in my earlier paper (4) are in error, since the sample was not decolorized. Fortunately, the extent and type of this error is of such a nature that the general conclusions reached are valid. Decolorization would have given higher levulose and lower dextrose percentages.

The results shown in Table 1 with three quite dissimilar apple varieties and with Elberta peaches in two seasons show that decolorization of the sample solution is highly desirable when the Lothrop and Holmes method for the determination of dextrose and levulose is used. Although water at room temperature was used for sugar extraction in the samples discussed above, tests have shown that alcohol extraction of sugar from fruit samples also extracts pigments which are not entirely removed in clearing and which are oxidized by iodine, thus introducing an error in the dextrose percentage. Decolorization is a simple procedure and does not detract from the desirability of the Lothrop and Holmes method.

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The Influence of Methyl Bromide on the Rate of Respiration and Softening of Apples

By F. W. SOUTHWICK, *University of Connecticut, Storrs, Conn.*

RESULTS presented in earlier reports (2, 6) have shown that methyl bromide, at a concentration of ¼ pound per 1000 cubic feet for 4 or 5 hours, is very effective in controlling rodents at cold storage temperatures.

Visible injury to apples treated with methyl bromide for insect control has been reported (2, 3, 4). The concentration, temperature, and period of exposure suggested for rodent control with methyl bromide in apple cold storages are considerably different from those employed for insect control, however. Therefore, further studies were necessary to determine the influence of this fumigant on apples treated under cold-storage conditions. Since treatments with organic vapors such as ethylene (5) may shorten the storage life of apples, it was considered necessary to measure the influence of various concentrations of fumigant on the rate of respiration and ripening of apples of different maturities. The appearance and nature of visible injury have also been recorded.

METHODS AND MATERIALS

All respiration measurements were made on lots of fruit gathered from the University orchard at Storrs, Connecticut. From 45 to 60 apples were placed in half-bushel containers. The containers holding the fruit were submerged in a constant-temperature water-bath at 75 degrees F (±0.5 degrees F). Air movement over the fruit and through absorption towers was effected by the use of a mercury pump. The carbon dioxide was absorbed in 100 ml of approximately 0.1 N. sodium hydroxide in absorption towers, each of which was fitted with a frittered-glass disc at the base. After absorption the carbonates were precipitated out, as barium carbonate, by adding barium chloride to the solution. An aliquot of the supernatent liquid was then titrated with standardized hydrochloric acid, using phenolpthalein as the indicator. All respiration measurements lasted 2 hours, and the carbon dioxide content was calculated as milligrams per kilogram of fruit per hour.

The temperatures at which the fruit was held before, during, and after treatment are discussed in the text. In calculating the quantities of methyl bromide for any given concentration, only the space unoccupied by the fruit was considered. It was found that the apples displaced approximately 50 per cent of the space in the containers. The fumigation period lasted 5 hours in all instances.

The loss in firmness, from the time of fumigation and to the conclusion of the respiration determinations, was obtained with a Magness pressure-tester.

Results

The rate of respiration and ripening of apples is stimulated by the addition of ethylene before the climacteric rise in respiration, but not at later stages of maturity (5). In an effort to determine whether methyl bromide influenced the rate of respiration and the ripening of apples in a manner similar to that of ethylene, two groups of apples were selected early preclimacteric (Class I) and a later stage when low concentrations of ethylene are known to be ineffective in hastening ripening (Class II). These classifications are employed merely to simplify the presentation of the data.

Class I

McIntosh:—The apples used were picked on August 30, 1944, and were immediately weighed and placed at 75 degrees F, and the rate of respiration determined for two days prior to treatment. On September 1 the lots of fruit were subjected to 0, ¼, ½, 1, 2, and 4 pounds of methyl bromide per 1000 cubic feet of free air space for five hours. The results are given in Fig. 1.

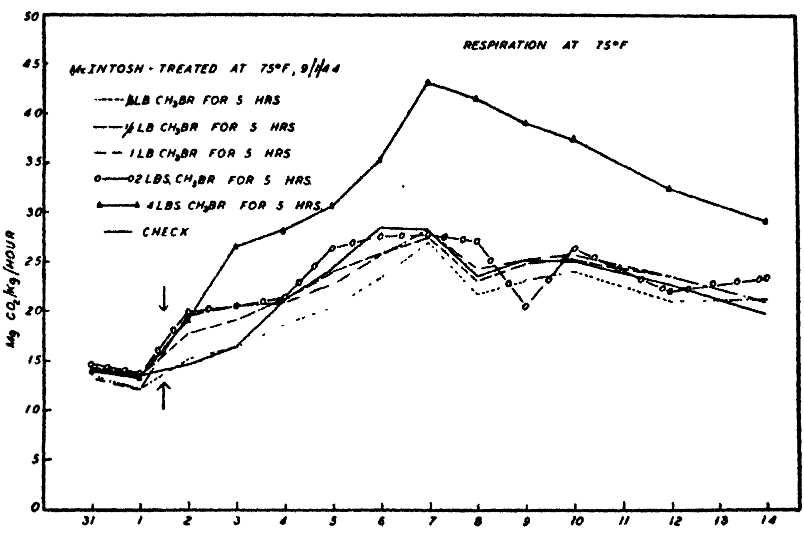

FIG. 1. The influence of methyl bromide on the rate of respiration of McIntosh apples.

The data indicate that all concentrations except the ¼-pound dosage hastened the rate of respiration. The 4-pound concentration caused the apples so treated to respire at an exceedingly rapid rate two days after exposure to the fumigant. The influence of the ¼, ½, 1, and 2-pound treatments on the rate of softening (Table I, Test No. 1), was so slight that the loss in firmness was not significantly different from that of the control lot. The fact that the apples treated with

TABLE I—The Effect of Methyl Bromide on the Rate of Softening of Apples

Date Picked	Date Treated	Treatment			Stored After Treatment				Loss in Firmness‡ (Pounds)
		Conc (Lbs)	Hrs	Temp (Degrees F)	Days		Temp (Degrees F)		
					A**	B†	A**	B†	
Test No. 1, McIntosh Variety									
Aug 30	Sep 1	¼	5	75	—	13	—	75	6.0
		½	5	75	—	13	—	75	6.1
		1	5	75	—	13	—	75	6.5
		2	5	75	—	13	—	75	6.8
		4	5	75	—	13	—	75	1.9
		0	5	75	—	13	—	75	6.1
Test No. 2, Rome Beauty Variety									
Sep 25	Sep 26	¼	5	37	3	11	75	75	4.6
		½	5	37	3	11	75	75	4.2
		1	5	37	3	11	75	75	5.1
		2	5	37	3	11	75	75	4.7
		4	5	37	3	11	75	75	4.3
		0	5	37	3	11	75	75	3.7
Test No. 3, McIntosh Variety									
Sep 25	Oct 17*	¼	5	32	1	19	75	75	4.4
		½	5	32	1	19	75	75	4.4
		1	5	32	1	19	75	75	4.5
		2	5	32	1	19	75	75	4.4
		4	5	32	1	19	75	75	4.4
		0	5	32	1	19	75	75	4.3
Test No. 4, McIntosh Variety									
Sep 25	Oct 17*	¼	5	32	49	11	32-36	75	4.3
		½	5	32	49	11	32-36	75	3.9
		1	5	32	49	11	32-36	75	3.8
		2	5	32	49	11	32-36	75	4.3
		4	5	32	49	11	32-36	75	3.7
		0	5	32	49	11	32-36	75	3.9

*Stored at 32-36 degrees F until time of treatment.
**Prior to the respiration measurements.
†During the respiration measurements.
‡At the end of the respiration measurements.

4 pounds of methyl bromide were so much firmer than those in the other lots is surprising. Usually there is a close correlation between the rate of respiration and softening of apples.

The fruits treated with 4 pounds of fumigant showed 100 per cent severe internal injury, but only slight external injury, at the end of the experiment. The internal injury appeared as browning at the endocarp, as well as considerable browning of the flesh outside of the core line, often at, or adjacent to, the vascular bundles. However, the external symptoms appeared almost exclusively as a band ¼ to ½ inch wide around the calyx end. The damage became more extensive both internally and externally when the apples were left at room temperature. The fruits treated with 1 and 2 pounds of methyl bromine showed 30 and 50 per cent of slight internal injury, respectively. The damage appeared in the flesh as one or more brown spots ¼ to ½ inch in diameter. No external effects were visible.

Rome Beauty:—The apples used in this test were picked on September 25. Immediately after picking they were placed in the con-

tainers at 37 degrees F, and treated at this temperature with various concentrations of methyl bromide for five hours. From the data presented in Fig. 2, it appears that the respiratory rates of all lots of treated fruit were stimulated somewhat by methyl bromide. The results, given in Table I, Test No. 2, show that all fumigated lots of apples were softer than the controls. At the end of the experiment no injury was visible either externally or internally.

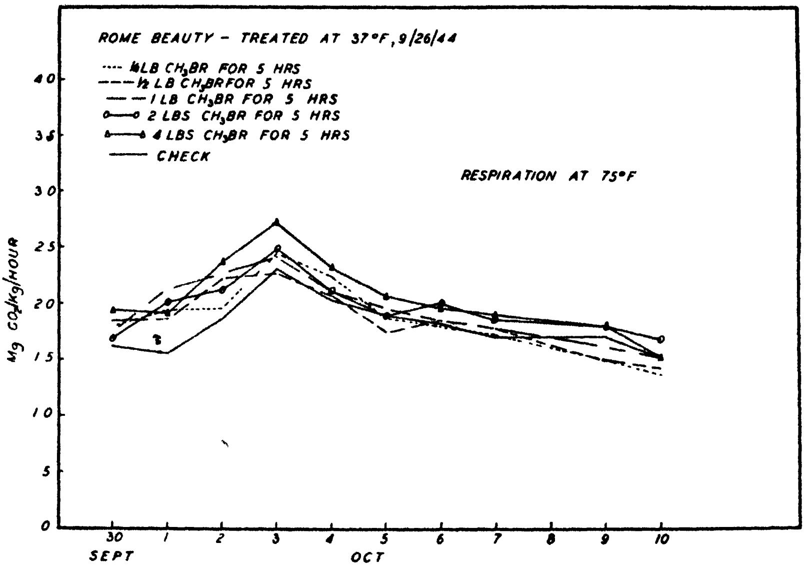

FIG. 2. The influence of methyl bromide on the rate of respiration of Romė Beauty apples.

CLASS II

McIntosh:—The apples selected for this experiment were picked on September 25 and stored at 32–36 degrees F until they were treated at 32 degrees F on October 17. From the results, presented in Fig. 3, it appears that these apples had definitely started on their preclimacteric respiratory rise before treatment with methyl bromide. The respiratory curves and loss-in-firmness data (Table I, Test No. 3), do not indicate any significant hastened-ripening effects from methyl bromide.

One-third of the apples treated with 4 pounds of fumigant exhibited an injury markedly different from the other McIntosh apples treated at 75 degrees F and discussed under Class I. The injury was almost entirely external and appeared as brown spots ⅛-to ⅜-inch in diameter. The periphery of a spot was often depressed, leaving an unsunken portion in the center. The flesh under these spots was occasionally injured to a depth of $^{1}/_{16}$ inch under these spots. A few small brown areas were present in the interior of some apples. It is conceivable that the difference in injury to thèse apples and those fumi-

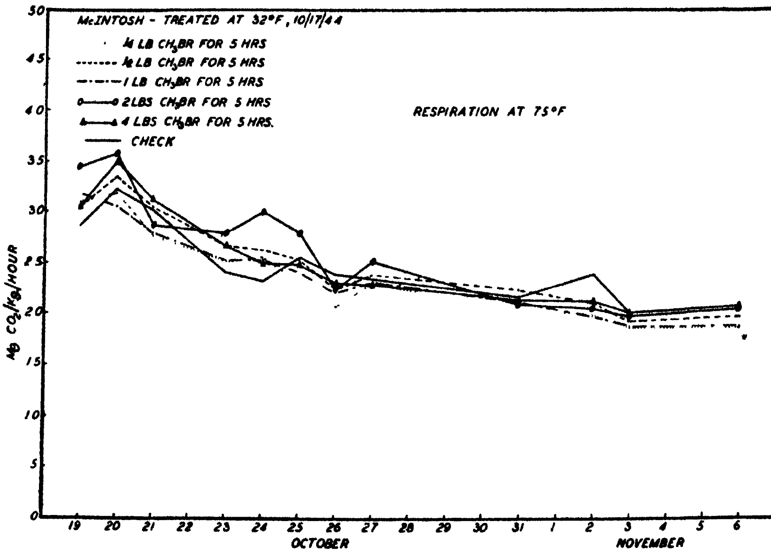

FIG. 3. The influence of methyl bromide on the rate of respiration of McIntosh apples.

gated at 75 degrees F may have been due to differences in maturity as well as to temperature at the time of treatment.

Other lots of McIntosh, picked and treated in the same manner as discussed in this section, were left in storage at 32–36 degrees F until December 5 (49 days after treatment). The results shown in Fig. 4 and Table I, Test No. 4 indicate that these dosages of methyl bromide have no ripening influence on McIntosh when treated at this stage of maturity and held in cold storage. There was some surface injury on a third of the apples treated with 4 pounds of fumigant. The injury was similar to that which appeared on the other lot of McIntosh discussed in this section. No internal injury was observed, however.

Discussion

It appears that the dosage of methyl bromide necessary for satisfactory rodent control in cold storages (¼ pound per 1000 cubic feet for 4 or 5 hours) will cause no visible injury to apples. In these experiments a concentration, eight times that necessary for control of rodents, resulted in no visible injury at 32 degrees F.

It appears, however, that methyl bromide influences respiration of apples in their early preclimacteric phase was usually stimulated somewhat by exposure to methyl bromide even in the absence of visible injury. The rate of softening may be accelerated at this time, but further work must be done to determine how serious this may be for fruit held in storage an entire season following fumigation. Fruit at a later stage of maturity did not respire or soften at a rate significantly different from that of similar untreated fruits.

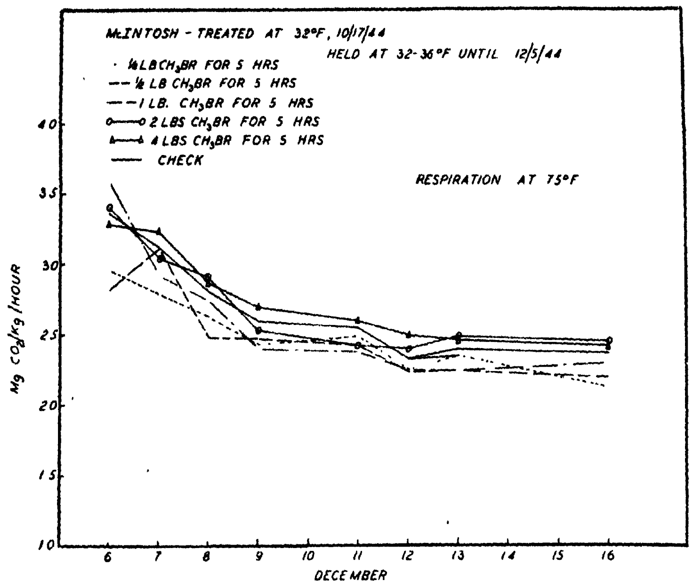

FIG. 4. The influence of methyl bromide on the rate of respiration of McIntosh apples.

Since apples in the later stages of maturity were apparently not influenced measurably by concentrations of methyl bromide necessary for cold-storage rodent control, four fumigation trials were conducted in a large commercial apple-cold-storage plant in New York State in February and March, 1945. The rooms ranged in capacity from 54,000 to 108,000 cubic feet, and were from quarter to half full of fruit at the time of fumigation. It was estimated that 50,000 bushels of mixed varieties were subjected to the methyl bromide treatments at 32 degrees F.

In these tests a total of 49 caged white rats were placed amongst the crates and throughout the rooms. A concentration of ¼ pound of methyl bromide per 1000 cubic feet of free air space was used for 5 hours. The mortality of the caged rats was 100 per cent in each instance, and frequently dead mice were seen on the floor following the treatment. No evidence of injury to the fruit or development of "off" flavors was observed.

SUMMARY

The results of this study indicate that rodent control with methyl bromide in apple cold storages is possible without any measurable effect on the fruit. Apples that have not commenced their climacteric rise in respiration may have their storage life shortened, however. Therefore, it may be advisable to delay the time of fumigation until

the apples have been held in storage a few weeks after harvesting and it is reasonably certain that the climacteric rise in respiration has begun.

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Surface and Volume Determinations of Citrus Fruits[1]

By F. M. TURRELL, JANE P. CARLSON, and L. J. KLOTZ, *University of California Citrus Experiment Station, Riverside, Calif.*

RESEARCH studies in the fields of entomology, pathology, physiology, and chemistry often require estimates of surfaces and volumes of spherical and nonspherical fruits, nuts, and vegetables. Surface and volume measurements enter into calculations of amounts of space for storage and shipping, and of sprays, toxic gases, and dusts which are applied in the control of pests; they are also needed in calculating respiration, water loss or absorption, and temperature data.

While measurement of volume presents no great difficulty, in the materials, knowledge, or time required for the calculation, estimation of surface area may be impeded by any failure or lack in any one of these respects. Bartholomew *et al.* (1) used an abbreviated formula and prepared a chart for estimating the surface area of Valencia oranges. Hansen (3) used a formula for finding the surface of prolate spheroids and then derived regression equations which may be used in estimating the surface of Placentia walnuts. Baten and Marshall (2) made a thorough study of various methods of determining surface areas of apples. They investigated determinations made from the surface of an ellipsoid, from transverse sections, longitudinal sections, diameter measurements, and weight. Their best estimate of surface was found to be that determined by weight, the maximum percentage of standard error being 7.64. They have expressed the relations between surface and weight for pears and plums by regression equations, and have given standard errors of estimate, coefficients of variability, and correlation coefficients.

Citrus fruits roughly approximate three geometric shapes: (a) oblate spheroids, which are shorter in polar diameter than in equatorial diameter, in which class grapefruits usually fall (Fig. 1, A); (b) spheres, which have polar and equatorial diameters of the same length, in which class some fruits of any of the citrus species, varieties, or strains may fall (Fig. 1, B); and (c) prolate spheroids, which are longer in polar diameter than in equatorial diameter, in which class Valencia oranges and lemons usually fall (Fig. 1, C).

After about three years of work, tables of surfaces and volumes for use in studies on citrus fruits at the University of California Citrus Experiment Station have been prepared under the title "Surface and Volume Tables for Oblate and Prolate Spheroids and Spheres" (4). Although designed particularly for use with citrus fruits, these tables may be used for cherries, dates (Deglet Noor), muskmelons, walnuts and pecans, and, by employing a change in the unit of measure, for exceedingly small bodies or very large ones. In fact, such tables as these, when available to agricultural workers, will increase the

[1]Paper No. 525, University of California Citrus Experiment Station, Riverside, California. The authors wish to express their appreciation to the Texas Gulf Sulphur Company for a grant in aid which has made this work possible, and to Mr. Alfred Fenton of that company for his interest in the work.

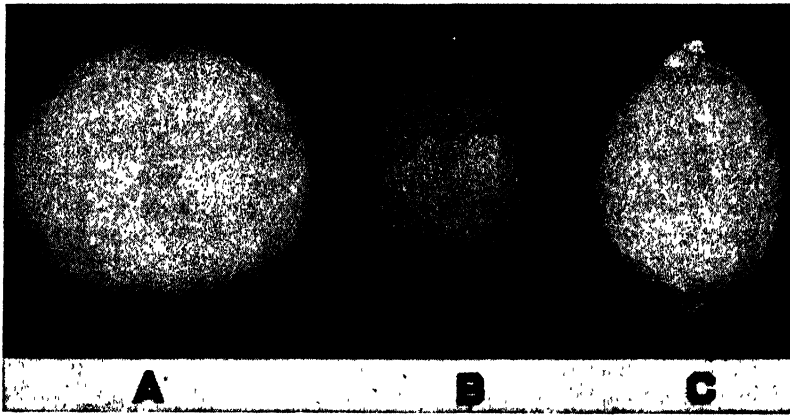

Fig. 1. Citrus fruits approximating geometric shapes as follows: (A) Marsh grapefruit, an oblate spheroid. (B) Washington Navel orange, a sphere. (C) Eureka lemon, a prolate spheroid.

rapidity of certain types of work with many different crops and will eliminate much duplication of effort.

The work reported in the present paper was designed to test the error involved in using the surface and volume tables (4) for estimation of surfaces and volumes of citrus fruit.

Materials and Methods

The fruits used in these studies were freshly picked Marsh grapefruits, Washington Navel and Valencia oranges, and Eureka lemons.

The surface or volume estimation for any fruit was found by measuring the major axis (the longer diameter) in two or more locations with a pair of calipers and taking an average, by measuring the minor axis (the shorter diameter) in a similar manner and taking an average, and then finding the difference between the major axis and the minor axis and using these measurements to determine the surface area or volume of the oblate or prolate spheroid or sphere of corresponding measurements in the surface and volume tables (4).

Surface measurements of citrus fruits were made in two ways, (I) by planimeter and (II) by photoelectric area determinator, for comparison with surface values found in the surface and volume tables (4).

I. The fruit peels were cut in sections with a sharp knife and peeled from the fruit without breaking. The albedo of the peel was subsequently partly removed with a knife, so that the peel was made considerably thinner. Cuts about 3/8 inch apart were then made across the remaining albedo in such a way that the peel would lie flat when the albedo side was down. Carefully penciled outlines were made of these sections, which later were carefully measured twice with a planimeter.

II. The peels were then placed between glass plates in a carefully calibrated photoelectric area determinator,[2] and the surface area was measured.

Volume measurements were made by displacement of water from a 1-gallon tin-plated can fitted with an overflow spout near the brim (Fig. 2A). The fruit was completely immersed by means of a glass rod, to which was sealed a linoleum disk fitted with four long pins (Fig. 2B). The displaced water was caught in the smallest glass graduated cylinder adequate to catch the fluid. The accuracy of this method was tested by immersing in the displacement can, individually and collectively, two standard steel cylinders accurately machined to 118.69 and 118.94 cubic centimeters,[3] respectively (Fig. 2C).

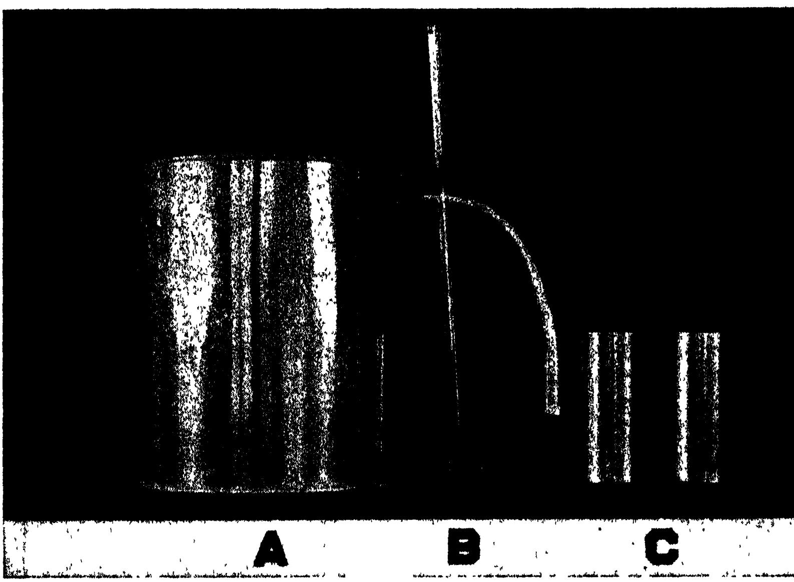

FIG. 2. Apparatus used in making volumetric measurements of citrus fruits and of standard steel cylinders. (A) 1-gallon tin-plated displacement can fitted with overflow pipe. (B) Glass rod fitted with linoleum plate and long pins. (C) Standard steel cylinders nos. 1 and 2.

In making estimations of fruit surface from the surface and volume tables (4), a fraction greater than 0.5 millimeter on the major or minor diameter, as measured with the calipers, was raised to the next millimeter. When the decimal value was 0.4 or below, the decimal was dropped, because the major and minor diameters are given only to the nearest millimeter in the tables (4).

[2] No. 7-345 Aminco Area Determinator, manufactured by the American Instrument Company, Silver Springs, Maryland.

[3] Machined by Mr. Henry Meyer of the University of California Citrus Experiment Station.

Results

Since the surface and volume tables (4) were calculated for perfect spheroids and spheres, and citrus fruits are seldom perfect in shape, certain errors may be expected in the practical application of the values given in the tables (4).

In the course of this investigation, frequency-distribution curves of citrus-fruit equatorial diameter showed that samples of Marsh grapefruits, Washington Navel oranges (two samples), Valencia oranges, Eureka lemons, and calamelos (a cross between the calamondin and the pummelo), consisting of 135, 153 and 61, 231, 77, and 75 individuals, respectively, were not normally distributed. The curves for grapefruits and lemons were not skewed—that is, the mean and median values for these fruits did not fall in different classes, but in the same class. But curves for Washington Navel (Fig. 3) and Valencia oranges, and for calamelos, were skewed. The curves for all

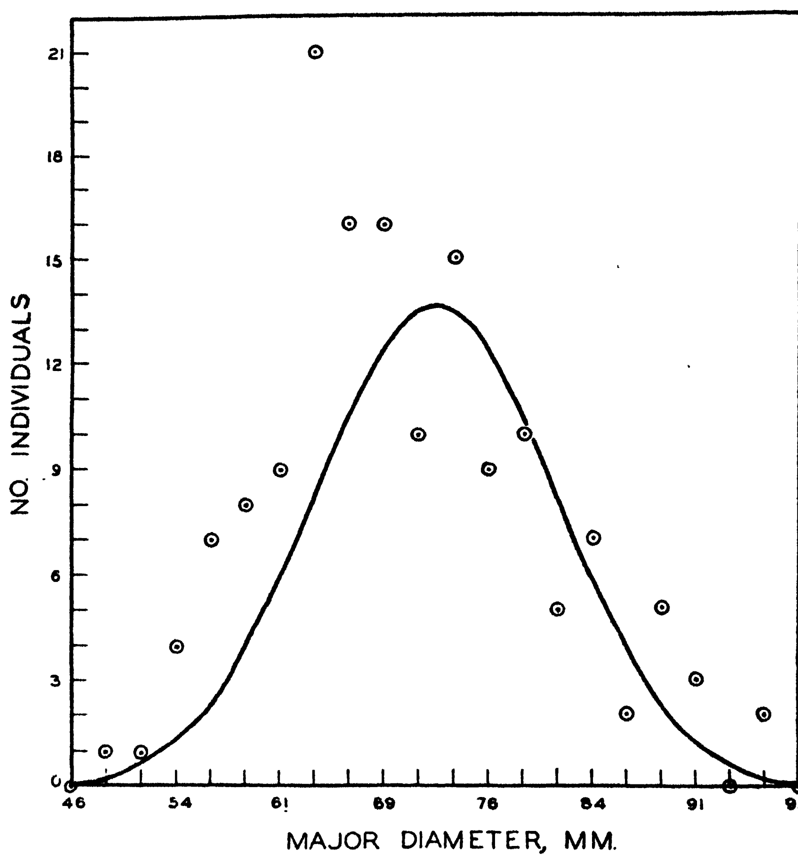

Fig. 3. Frequency distribution of major diameters of a sample of Washington Navel oranges in comparison with a normal frequency-distribution curve. Note that an imaginary curve through the points would be skewed.

types of fruit showed kurtosis—that is, the tops of the curves were broader than would be expected for normal curves. This indicated that the standard error of estimate of regression equations, based on assumed normal distribution curves, would not lead to a true estimate of error. Therefore, percentage errors only, have been calculated.

The average percentage differences in surface areas determined by three methods are shown in Table I. The average percentage differ-

TABLE I—COMPARISON OF SURFACE AREAS OF VARIOUS CITRUS FRUITS, DETERMINED FROM TABLES* AND BY PHOTOELECTRIC† AND PLANIMETER METHODS

Kind of Fruit	Number of Fruits in Sample	Average Surface Area Determined by			Percentage Difference Between Values Determined from Tables* and by	
		Tables* (Sq Cm)	Photoelectric Method (Sq Cm)	Planimeter Method (Sq Cm)	Photoelectric Method	Planimeter Method
Marsh grapefruit	10	187.11	194.69	190.42	3.83	2.23
Washington Navel orange	10	141.97	138.65	137.46	2.39	3.28
	153	150.43	155.6	—	3.41	—
Valencia orange	8	121.46	—	115.83	—	5.59
Eureka lemon	10	98.45	96.73	95.03	2.66	4.04

*Surface and Volume Tables for Oblate and Prolate Spheroids and Spheres (4).
†Aminco Area Determinator.

ence between the values for fruit surface found in the surface and volume tables (4) and those determined by the photoelectric area determinator varied from 2.39 per cent for Washington Navel oranges to 3.83 per cent for grapefruit, while the percentage difference between table values (4) and the values determined by the planimeter method varied from 2.23 per cent for grapefruit to 5.59 per cent for Valencia oranges. Examination of the values shown in Table I indicates that the agreement between values for surface area determined by the planimeter and photoelectric methods is not much better than the agreement between the values found in the surface and volume tables (4) and those determined by either of the two methods of direct measurement, even though both the photoelectric and the planimeter methods require removal of the peel from the fruit.

Table II shows that the percentage differences in volume values found by use of the surface and volume tables (4) and by displacement of water in a measuring container, varied from 1.95 per cent for Eureka lemons to 8.35 per cent for Marsh grapefruit.

Tests of how well surface and volume measurements could be duplicated by any given method were made by remeasuring the fruit. The results given in Table III show that photoelectric and planimeter measurements of surface may be duplicated to less than 1 per cent, and that volume measurements may be duplicated within 4 per cent. Thus the percentage differences between methods shown in Tables I and II cannot be attributed to variability in the operation of the measuring instruments alone.

TABLE II—COMPARISON OF VOLUMES OF VARIOUS CITRUS FRUITS, AS DETERMINED FROM TABLES* AND BY VOLUMETRIC DISPLACEMENT

Kind of Fruit	Number of Fruits in Sample	Average Volume Determined by		Percentage Difference
		Tables* (Cu Cm)	Volumetric Displacement (Cu Cm)	
Marsh grapefruit	30	254.48	277.67	8.35
Washington Navel orange	31	80.80	83.61	3.36
	5	179.78	189.90	5.44
	5	185.84	193.60	4.07
Valencia orange	50	70.11	72.80	3.70
	5	176.15	186.45	5.26
	5	182.17	190.60	4.44
Eureka lemon	51	43.95	44.82	1.95

*Surface and Volume Tables for Oblate and Prolate Spheroids and Spheres (4).

DISCUSSION

The percentage of error in making surface-area measurements of citrus fruits by the photoelectric method is caused by the extensibility and compressibility of the rounded section of the peel, and by peel thickness, which causes diffraction of light in the area determinator. The error in the planimeter method is caused by the extensibility and compressibility of the rounded section of the peel when it is being flattened out for pencil tracings, and by the inaccuracies arising in making outline drawings of portions of the peel, as the radial walls of the peel, when flattened, are not perpendicular to the surface of the drawing paper.

The large percentage of error in measuring volume of fruit is not due to the method used, as indicated by the measurements of the standard steel cylinders, in Table III.

TABLE III—ACCURACY OF METHODS, BASED ON DUPLICATE MEASUREMENTS OF SAME FRUITS

Method of Measurement	Item Measured	Number Used	Mean Percentage Difference Between Measurements
	Surface Area		
Photoelectric Area Determinator	Grapefruits	5	0.96
Planimeter	Oranges	10	0.18
	Volume		
Volumetric displacement	Oranges	10	1.98
	Standard cylinder No. 1	10*	1.90
	Standard cylinder No. 2	10*	3.40
	Standard cylinder Nos. 1 and 2	10*	0.13

*Each cylinder measured ten times.

With three significant figures in the functions in the Surface and Volume Tables for Oblate and Prolate Spheroids and Spheres (4), there is a much higher degree of accuracy inherent in the table values, both for surface and for volume estimations of perfect spheroids, than in direct measurements of fruits. The application of the table values (4) to fruits which are not perfect in shape causes an error, however, as does the fact that the arguments are given to only two significant

figures in the first part of these tables (4). Also, all arguments in the surface and volume tables (4) are given in tenths of centimeters, whereas fruit diameters can be measured to hundredths of centimeters. Greater accuracy can be obtained from the surface and volume tables (4) by interpolation; but the degree of accuracy of an interpolated value varies for different value ranges, and as there are two variables, interpolation is awkward and time-consuming.

Comparisons of the various methods of estimating surface and volume of citrus fruit, as to time and equipment required, and cost, showed that the use of the surface and volume tables (4) and calipers requires the smallest investment in equipment and the least time of any of the methods (5). Volume estimations may be made with equal ease by any of the methods noted. The average percentage of error which may be expected in the use of the surface and volume tables (4), however, is slightly larger than that in actual measurements.

Summary

Surface and Volume Tables for Oblate and Prolate Spheroids and Spheres (4) were found to be of value in estimating surfaces and volumes of such citrus fruits as Marsh grapefruit, Washington Navel orange, Valencia orange, and Eureka lemon. The average percentages of difference between actual surface and volume measurements of the fruits, determined by various methods, and the values determined from the surface and volume tables ranged from 2.23 to 5.59 per cent for surface area, and from 1.95 to 8.35 per cent for volume.

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The Terminology of Fruit Maturation and Ripening

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THE use of standardized terminology concerning the maturation and ripening processes in fruits is highly desirable in the publications of a scientific group such as the American Society for Horticultural Science. This is true not only because uniformity of terminology is, obviously, an attribute of scientific discussion, but also because the degree of maturation at harvest and of ripening after harvest are major determinants in the production of that degree of edible quality which will insure the wide-spread consumer acceptance upon which the future of the fruit industry depends.

It is the purpose of this publication to recommend a standard terminology for describing the processes of maturation and ripening in fruits. Two major problems will be discussed in relation to this terminology.

THE PROBLEM OF THE TERMS "MATURE" AND "RIPE"

The first of these terminology problems is based on the fact that as long as a fruit remains attached to the plant it is in a physiologically distinct environment in comparison with the same fruit after harvest, regardless of the method of handling the fruit after harvest. We are confronted, therefore, with the necessity of adopting suitable terminology for the developmental processes occurring in the fruit while it is still attached to the plant, and a separate and distinct terminology to embrace the physiological changes which occur in the fruit following harvest.

Fisher and Britton (5) attempted to make this distinction by the statement, "When a peach is growing on the tree and approaching the picking stage it is reaching *maturity;* after it is picked it softens and becomes *ripe*". However, after stating this terminology they violate it by defining the term "tree-ripe" as fruit which has reached an eating-ripe condition on the tree. Even though the fruit of many species and varieties will reach a stage of maturation suitable for immediate fresh consumption when left on the plant, the changes which it undergoes in reaching this condition are inevitably different from the post-harvest changes in picked fruit regardless of the stage of maturation at harvest. Therefore, the term "tree-ripe" should not be used if the pre-harvest and post-harvest environmental and consequent physiological conditions are to be kept separate and distinct by suitable terminology.

Examination of well-known and presumably widely-used pomological textbooks shows a woeful lack of any attempt to discriminate between the pre-harvest and post-harvest condition as far as terminology is concerned. Typical examples are found in texts by Chandler

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[1]Suggestions and criticisms are hereby acknowledged from J. O. Kraehenbuehl, Professor of Electrical Engineering, on that part of the paper concerning color; and from Dr. W. A. Ruth and Dr. Dillon S. Brown of the Department of Horticulture on the remainder of the paper. The author assumes full responsibility for the opinions expressed.

(2) and by Gourley and Howlett (6) in both of which terms related to maturation and ripening are used interchangeably with no attempt at standardization.

The words "mature" and "ripe" and their derivatives are most frequently used in the literature, but usually quite indiscriminately. Some authors (1, 5) have made a clear definition of terms, while others (4, 10) have used the terms "mature" and "ripe" and their derivatives quite interchangeably. Fisher (4) states: "Ripening may occur either before or after harvest and is accompanied by a softening of the flesh and an increase in juiciness and aroma". This, obviously, is the use of the same term to indicate two separate and distinct phenomena.

The general lack of standard terminology has resulted in the use of a wide variety of terms, such as "hard-ripe," "firm-ripe," "soft-ripe," "tree-ripe," "green," "immature," "mature," "over-mature," "over-ripe" and so on, even including "green-ripe." The very lack of standardization necessitates considerable definition and explanation by each author if he is to make certain that the reader understands the meaning that he is attempting to convey.

A further, and very important, reason for standardization is the increasing use of the term "tree-ripe" by retail agencies for its presumed sales appeal, particularly with peaches. In addition to the objections to this term already mentioned, it leads the consumer to expect fruit which was allowed to mature before harvest; this is too frequently not the case.

Recommendations for the Terms "Mature" and "Ripe"

A. "Mature" and Its Derivatives:—In view of the facts presented above it is recommended that the term "mature" and its derivatives be restricted to the fruit while it is still attached to the plant, in accordance with the following definitions:

1. Mature:—That stage of fruit development which will insure the attainment of maximum edible quality at the completion of the ripening process. (See "ripe" and "ripening" below.) Only fruit which is mature at harvest can attain maximum edible quality, that is, become ripe. It is incorrect to refer to one lot of fruit as being more mature than the other; it can be only more nearly mature.

2. Maturity:—The condition of being mature. There is only one stage of maturity, that at which the fruit is mature. Therefore, stages or degrees of maturation should be referred to, not stages or degrees of maturity.

3. Maturation:—The developmental process by which a fruit attains maturity. This term should be restricted to the last third or fourth of the interval from blossoming to harvest.

4. Optimum Maturation:—Since the method of handling the fruit after harvest affects the rate and degree of the physiological changes it is desirable to use this term with a qualifying statement concerning the method of handling and proposed use. For example, there is an optimum stage in the maturation process at which Jonathan apples should be picked if they are to be held in cold storage until late December or early January. On the other hand, if they are to be used soon after

harvest for fresh consumption or for processing, the quality of the product can be improved materially by allowing maturation to proceed to maturity.

5. *Post-maturation:*—Changes occurring in the fruit after it has reached maturity, but is still attached to the plant. This is most frequently encountered in the soft fruits, and is characterized by extreme softness, evidence of tissue breakdown, and deterioration in flavor. Since various degrees of post-maturation are possible, this term should be used with a qualifying clause or statement.

6. *Post-mature:*—Any particular stage of post-maturation, identified by suitable qualifying terminology.

7. *Post-maturity:*—The condition of being post-mature.

8. *Over-mature and Over-maturity:*—Usually used to mean the same as post-mature and post-maturity. Should be considered obsolete since they are not as expressive of the actual conditions encountered as are post-mature and post-maturity.

9. *Immature:*—Any stage of development preceding the attainment of maturity. Since a fruit is immature throughout that portion of its developmental period preceding maturity, this term should be used in connection with some qualifying term or terms.

10. *Immaturity:*—The state or condition of being immature.

11. *Green*·—This term has been used frequently to designate immaturity. When used for this purpose its meaning is too ambiguous to have any real value. It is recommended that whenever it is used it be described in terms of its three attributes: hue, value, and chroma (see paragraph on Munsell system).

B. *"Ripe" and Its Derivatives:*—It is recommended that the term ripe and its derivatives be restricted to the physiological changes and conditions which occur in the fruit following harvest, in accordance with the following definitions.

1. *Ripe:*—The condition of maximum edible quality attained by the fruit following harvest. Only fruit which is allowed to become mature before harvest can become ripe. Fruit harvested when still immature cannot become ripe, but can proceed through the ripening process only to some stage of ripening which will be determined by the degree of maturation at harvest.

2. *Ripeness:*—The condition of being ripe.

3. *Ripening:*—The post-harvest physiological process by which the fruit attains ripeness. If the fruit is mature when harvested ripening proceeds to ripeness; if the fruit is immature when harvested ripening cannot proceed to ripeness, but only to some stage of ripening.

4. *Ripen:*—To undergo ripening; also to place in a ripening environment.

5. *Post-ripening:*—Changes occurring in the fruit after it has reached ripeness.

6. *Post-ripe:*—Any particular stage of post-ripening. It should be used with qualifying terms to indicate the degree of post-ripeness.

7. *Post-ripeness:*—The condition of being post-ripe.

8. *Over-ripe and Over-ripeness:*—Usually used synonymously with post-ripe and post-ripeness. Should be considered obsolete, since they

express conditions less accurately than do post-ripe and post-ripeness.

9. Unripe:—Not ripe, either because ripening has not progressed long enough or because the fruit was immature when harvested and cannot, therefore, attain ripeness.

10. Unripeness:—The state or condition of being unripe.

THE PROBLEM OF COLOR TERMINOLOGY

The second important terminology problem is the lack of standardization of color terms used to describe maturing and ripening fruits. References to background color changes in fruits are numerous but they frequently leave much to be desired. Morris (11) describes four color groups used for classifying peaches into four stages of maturation. The difficulty with such descriptions is that they provide no standard to which the reader can refer. Consequently, the transferal of the mental image of a color from the investigator to the reader inevitably introduces an error in the reader's perception of the color which the investigator has attempted to describe. This error may be quite significant in the case of individuals who are not familiar with the characteristics of the color development of the particular fruit in the region concerned.

Attempts have been made to provide charts, such as the socalled U.S.D.A. chart (10), to be used as a guide in determining the relation between background color in apples and degree of maturation. Here again the objection may be raised that the proposed color guides refer to no standard colors and frequently fail to portray background colors actually experienced in the orchard.

In studying peach maturity, Coe (3) used background colors taken from a color dictionary (9). This system has the advantage of referring to a standard which can be looked up by the reader. It has the disadvantage that color dictionaries do not necessarily base the colors on their physical characteristics and also introduce a multitude of color names which in themselves are meaningless and usually bear no relation to the physical characteristics of the color so designated.

In addition to the above shortcomings in color terminology now used in regard to fruits, some very doubtful statements are found in well known publications. For example, Gourley and Howlett (6) state, in regard to the time of picking apples, "Probably the most reliable index of all is the change of the ground color from a leaf-green to a light greenish-yellow." And Fisher (4) says, "As most varieties of apples become mature, the ground color changes from a green very much like that of the leaves to a lighter shade and eventually to yellowish." Presumably these references are to the green color of apple leaves. It is highly improbable that the color of immature apples could ever correctly be referred to as leaf-green, particularly during the last half of the fruit developmental period. In substantiation of this statement Fig. 1 shows typical spectral reflectance curves (8) for the upper (ventral) surface of fully-grown leaves free from spray and other foreign matter and the background color of fruits from the same Jonathan tree. It can be seen that the leaf reflectance was much less than the fruit reflectance. The comparatively low reflectance for the

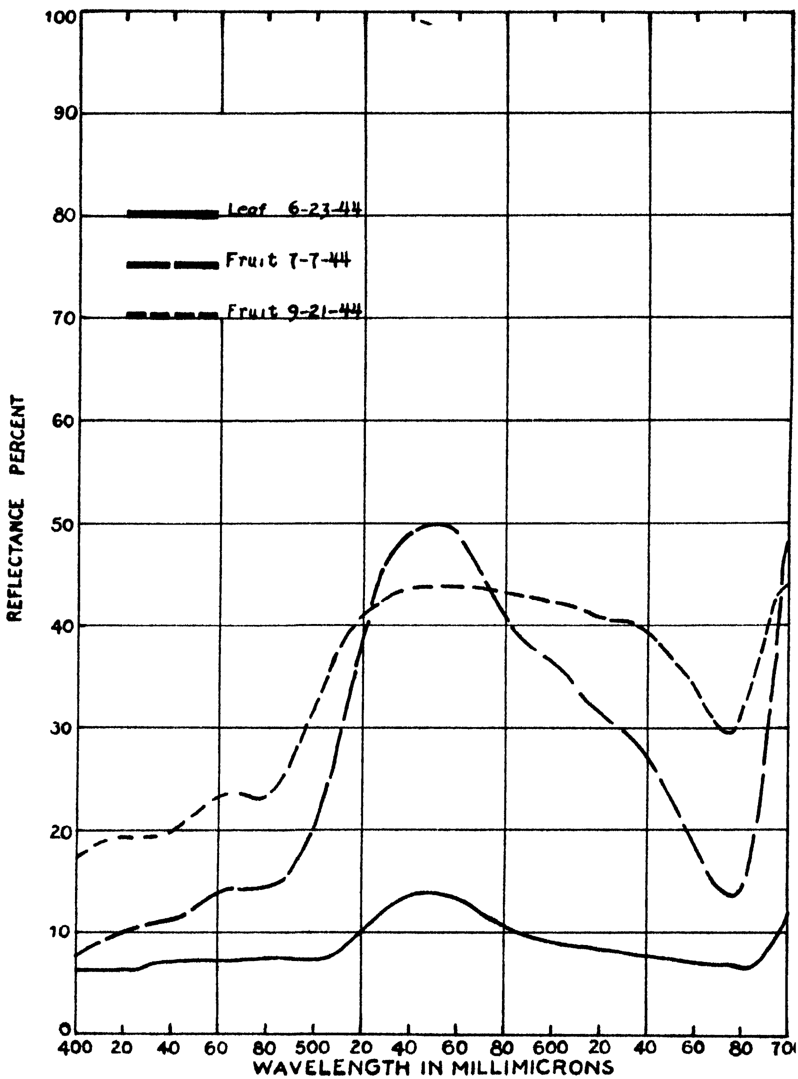

FIG. 1. Spectral reflectance curves from Jonathan: upper surface of leaf, background of midseason fruit, background of fruit at optimum maturity.

leaves at all wavelengths is what should be expected because of the dark color of the leaves with consequent high absorption of light. The curves show definitely that the ground color of the very immature fruit was much lighter (higher in value) than the leaves and of a very different spectral distribution. Furthermore, spectral reflectance measurements of the skin of very immature fruit and of leaves of several other varieties showed the same general types of spectral distribution

and reflectance values very similar to those shown in Fig. 1. Note that at optimum maturity (9–21) the ground color was characterized by increased reflectance in all regions of the spectrum except in a part of the green region where a decrease occurred. The curve for the leaves on June 23 was practically the same as that for leaves during the remainder of the season.

The literature contains a multitude of terms, such as greenish-yellow, apple green, straw, grapefruit, and yellow-green, used to describe background colors of fruits; and a similar list, such as carmine, crimson, purplish, light red, and dark red to describe the blush of fruits. Such terms are too general and ambiguous to have any scientific value and have the additional disadvantages previously mentioned of referring to no standard color and of bearing no relation to the physical properties of the color in question. To illustrate the inadequacy of such terms, it may be pointed out that, in the Munsell system of color notation (12), the charts ranging from greenish-yellow to yellowish-green show 146 hues, approximately 40 of which might well match fruit ground colors. The charts showing the yellow, red; and purple hues and their combinations which might match the background and anthocyanin colors of fruits at or near maturity show a comparable number of hues. It is obvious that, in the publication of results of research investigations, more specific color terminology than that in common use is needed.

Recommendations for Color Terminology

As a means of standardizing the color terminology of fruits the following recommendations are made:

Use of a Spectrophotometer:—Color should be measured with a spectrophotometer when one is available. Spectrophotometric measurements express colors on the basis of their physical characteristics, and thus make possible a purely objective specification for the color of a surface such as the skin or some other part of a fruit. The spectral reflectance curve of a material constitutes a permanent record and, furthermore, the units in which the curve is expressed are understood and accepted in foreign countries (7).

An automatic recording spectrophotometer is preferred because the time necessary for measurement is greatly reduced by its use. The time interval is very important when measuring flesh colors since the cut surface often oxidizes rapidly with consequent change in color. It was found that the use of an anti-oxidant introduced a greater color change than did natural oxidation of apple flesh during the interval necessary for measurement with the automatic recording machine (8).

The Munsell System of Color Notation:—Since a spectrophotometer may not be available in all research organizations, and in many cases color description away from the laboratory is necessary or desirable, it is recommended that in such cases the "Munsell Book of Color" be used (12). It clearly and definitely describes color in terms of its three attributes, hue, value and chroma; it is readily usable and internationally understandable. It can be obtained for a nominal sum in an abridged edition suitable for horticultural use.

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Some Results in Thinning Peaches with a Blossom Removal Spray

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MOST peach varieties, with the exception of Mikado and J. H. Hale, are self-fruitful. Cross pollination is, therefore, of little concern in the production of this fruit. Bearing peach trees of average to good vigor will set many more fruits than they can mature with desirable commercial size. Barring the loss of fruit buds by winter cold or blossoms by spring frost, the hand thinning of peaches is considered a necessary annual operation. In spite of its recognized importance, thinning is often one of the most neglected operations in peach production.

Blossom sprays consisting of dilute concentrations of sodium dinitro-cresylate (Elgetol) have been employed experimentally for thinning peaches by Batjer and Moon (1). In view of the results reported by these workers and the experience obtained with similar sprays for thinning apples (2), a number of tests were conducted in New York peach orchards in 1944.

The peach crop was a failure throughout the state in 1943 because of bud killing during the previous winter. As a result, most trees made excellent growth that season and formed an abundance of fruit buds, which came through the relatively mild winter of 1943–1944 without injury.

A 6-year-old block of trees, consisting entirely of Elberta located in the lower Hudson Valley, was used for one of these tests. The trees had received good commercial care and were vigorous and exceptionally uniform. A period of warm weather occurred in this area during the forepart of May and bloom development was very rapid. At noon on May 4 a few counts in the orchard showed that 7 to 10 per cent of the flowers were open. Twenty-four hours later, midday May 5, approximately 70 per cent of the flowers had opened and by 4 p. m. on that day it was estimated that 95 per cent or more of the bloom was open. The treatments listed in Table I were made between 4 and 6 p. m. on May 5. It was the aim to apply the materials when the trees reached approximately full bloom since some preliminary work had indicated that the greatest reduction in fruit set with a given concentration of toxicant could be accomplished at this stage of development.

Each treatment was applied to one entire row of 52 trees extending the full length of the block. Detailed records were taken on only the first 10 trees in each row. A buffer row was left between each of the treated rows to avoid any effect from drift. The trees were sprayed thoroughly by riding the rig and using a gun equipped with a $^{3}/_{16}$-inch disk. The rig operated at 500 pound pressure and each tree received an average of 7 gallons of material. Under the conditions of this test, there was no injury of any consequence resulting from any of the treatments. In the case of the dust row, some small discolored

TABLE I—EFFECT OF DINITRO SPRAYS AND DUST APPLIED AT FULL BLOOM ON THE SET, YIELD, AND SIZE OF ELBERTA PEACHES

No. of Trees	Treatment Concentration of Spray	Fruit Set (Per Cent)	Reduction in Set (Per Cent)	Mean No. Half-Bushel Baskets Per Tree	Mean No. Fruits Per Half-Bushel Basket	Prevailing Size Including 90 Per Cent or More of Crop (Inches)
10	Check	27±1.6	—	7.2±.43	220±7	1¾
10	Hand thinned	—	—	6.6±.34	191±6	2
10	Elgetol* 1 pint per 100 gallons	16±1.0	40	7.9±.37	133±3	2¼–2⅜
10	Elgetol* 1½ pint per 100 gallons	12±1.2	55	6.9±.42	113±4	2⅜
10	DN Powder** ½ pound per 100 gallons	14±0.5	48	7.0±.18	131±2	2¼–2⅜
10	DN Powder** ¾ pound per 100 gallons	14±1.2	48	6.5±.25	133±2	2¼–2⅜
10	Talc dust*** 5.0 per cent DNOC	12±0.5	55	7.3±.18	115±5	2⅜

*Sodium dinitro cresylate—liquid—1 quart contained 6.2 ounces DNOC.
**Ammonium dinitro cresylate—powder—1 pound contained 7.38 grams DNOC.
***Talc dust contained 5 per cent ammonium dinitro cresylate.

spots were observed several weeks after treatment on the bark of the previous year's shoot growth but there was no evidence of injury extending through to the cambium and nothing in the nature of cankers or gumming ever developed. A slight burning of the petals was the only means by which sprayed trees could be distinguished from unsprayed trees. Limited experience indicates that the peach is less susceptible than the apple to injury from dilute concentrations of dinitro materials.

For several weeks after the treatments were made, it was difficult to observe any difference between the set of fruit on treated and untreated trees, but by the first of June it became evident that a larger number of peaches were failing in their development on the sprayed and dusted trees than on the checks. By the time the June drop was under way, it was obvious that considerable thinning had been accomplished by all treatments.

The final fruit set counts were made on July 12 when it seemed certain that all fruits remaining would develop to maturity. The stronger concentration of sodium dinitro cresylate (Elgetol), 1½ pints per 100 gallons, reduced the set somewhat more than did the weaker concentration of 1 pint per 100 gallons, altho this was not highly significant. The reduction in fruit set was the same for both concentrations of ammonium dinitro cresylate applied as a liquid spray. No explanation can be given for this other than that some of the limbs selected for counts may have had a higher per cent of unopened flowers at the time the spray was applied than did others.

The reduction in fruit set obtained by dusting with a talc dust containing 5 per cent ammonium dinitro cresylate was considered very interesting. At the time the dust was applied, there was considerable wind and about 2½ pounds of dust was used per tree in order to obtain good coverage. This was a heavier application than was originally planned with a 5 per cent dust but the use of the material in this form was entirely exploratory and the results will serve as a basis for further work.

There was no significant reduction in yield by any of the treatments, the mean volume of fruit produced per tree being about the same in all cases. The reduction in the number of fruits per tree by the blossom sprays and dust was compensated for by an increase in size of individual fruits.

There would have been larger sized fruits produced by all trees and the relationship between size and yield may have been different in some cases had there been normal rainfall in this area through the summer. The rainfall in May and June was 1 inch less than the normal and only 3.8 inches fell during July and August which represented a total deficit of 6 inches for the four months' period. In addition to a lack of rainfall, high temperatures prevailed during the entire season. There was an average daily excess of 6.1 degrees in May, 1.2 degrees in June, and 1.4 degrees in July and 3.1 degrees in August. Rather serious drouth conditions had developed by harvest time and explains why the hand thinning performed by the grower in early July had so little effect on size.

The early thinning accomplished by the bloom treatments must have resulted in the conservation of considerable quantities of reserve materials which were available for the growth of roots and shoots because these trees made a much stronger shoot growth than did the checks or those hand thinned later in the summer.. After the leaves had fallen, ten terminals were measured on each of the ten trees in each treatment. The average length of terminal growth in inches for the different groups were as follows: Checks, 8.4; hand thinned 10.6, and blossom thinned 15.6. Counts of fruit buds on 50 terminals from each treatment showed that the check trees had formed an average of 4.5 buds per foot of growth while those thinned at blossom time had formed 12.1 buds per foot of growth. This difference in growth and fruit bud formation caused by early thinning should have considerable influence on the following crop. If root growth was affected in a similar way, then the trees thinned at blossom time were in a better condition to withstand the effects of the summer drouth than were those setting excessive amounts of fruit. A striking example of what might be explained on this basis was observed in the case of Golden Delicious apple trees in a neighboring orchard. Trees which were thinned at blossom time with a spray possessed normal foliage throughout the season, while the foliage on similar but unthinned trees wilted, scorched and dropped during August.

Western New York Tests

Five tests, including 4 varieties, were conducted in orchards located near Lake Ontario where the rate of bloom development was much slower than that described for the Hudson Valley. A few flowers were open in these orchards on May 6 but because of cool weather, due to the influence of the lake, the trees did not reach a stage of approximately full bloom until one week later. All treatments were made on May 13. At that time there were possibly 2 to 5 per cent of the flowers on some trees which were not entirely open.

Elgetol was used in these tests at concentrations of ½ pint, 1 pint and 1½ pints per 100 gallons, except in the case of the Rochester variety where only the strongest concentration was employed. Ten trees were included in each treatment. The spray was applied thoroughly so as to drench all flowers.

Unfortunately, it was not possible to obtain any data on yield or fruit size from these tests. However, a record of fruit set for all treatments was made on July 19 after the last drop had taken place. These data, given in Table II, were calculated from a count of 400 to 600 blossoms per tree located on three typical branches. Fruit set records will not serve to indicate the commercial size or quality of the crop because the number of buds and the per cent setting fruit vary considerably with the variety, type of wood growth, age of tree and other factors. These data do show, however, a close association in each case between the per cent of flowers setting fruit and the concentration of spray used.

TABLE II—EFFECT OF ELGETOL SPRAYS APPLIED AT FULL BLOOM ON THE SET OF PEACHES

Age Trees	Treatment. Amount of Toxicant per 100 Gallons	Fruit Set (Per Cent)	Degree of Thinning (Grower Opinion)
		Orchard 1—Halehaven	
	Check	20.1±1.1	Set too heavy
	½ pint	19.0±0.7	No thinning
	1 pint	9.0±1.1	Satisfactory amount
8 years	1½ pints	4.0±0.5	Thinning too severe
		Orchard 2—Elberta	
	Check	22.0±1.0	Set to heavy
	½ pint	11.0±0.7	Insufficient thinning
	1 pint	6.0±0.7	Satisfactory amount
8 years	1½ pints	4.0±0.2	Thinning too severe
		Orchard 3—Valiant	
	Check	13.0±0.8	Set too heavy
	½ pint	6.0±0.6	Satisfactory amount
	1 pint	4.0±0.4	Thinning too heavy
9 years	1½ pints	1.2±0.1	Thinning too severe
		Orchard 4—Elberta	
	Check	21.0±1.0	Satisfactory amount
	½ pint	11.0±0.9	Thinning too heavy
	1 pint	5.0±0.5	Thinning too severe
4 years	1½ pints	4.0±0.3	Thinning too severe
		Orchard 5—Rochester	
	Check	23.0±2.5	Set too heavy
18 years	1½ pints	5.0±0.6	Some hand thinning needed

The Halehaven and Elberta in orchards 1 and 2 were thinned to a satisfactory degree with a concentration of 1 pint per 100 gallons. Possibly the Halehaven crop receiving this concentration might have profited by some additional hand thinning. The trees in these two tests were not considered as vigorous as the Elberta used in the Hudson Valley work which may explain why in this case the concentration of 1½ pints per 100 gallons resulted in excessive thinning. On the other hand, it is likely that the lack of moisture in the Hudson Valley area may have served as an advantage to those treatments causing the greatest amount of thinning.

The Valient trees in orchard 3 were located on a heavy soil, not well adapted to peaches. The previous season's shoot growth averaged about 12 inches in length but it was thin and possessed a light-to-moderate amount of buds. Under these conditions the weakest concentration of ½ pint per 100 gallons thinned the crop sufficiently while the stronger concentrations caused too great a reduction in set.

The Elberta trees in orchard 4 were 4 years of age and the shoot growth was very vigorous. Much of it showed secondary branching and a small number of fruit buds which is often characteristic of young trees. As the season progressed, it became apparent that the unthinned checks would size their crop satisfactorily and that all spray treatments had resulted in excessive thinning.

Under favorable conditions, the variety Rochester consistently sets heavy crops of fruit. The trees in orchard 5 were vigorous and heavily budded. Only one concentration of spray, 1½ pint per 100 gallons, was used in this test. The treatment reduced the set from 23 per cent to 5 per cent and in the opinion of the grower it seemed desirable to supplement the spray with a limited amount of hand thinning.

Considering the fact that mature peach trees with a full complement of live buds usually set too many fruits and require much hand thinning, it seems that bloom sprays offer some promise of partially accomplishing this job. Preliminary experience with the dinitro materials for this purpose indicates that the concentration should be varied according to such factors as variety, vigor, type of growth and amount of bloom. The range in effective concentration appears to be roughly between 2 and 5 ounces of soluble toxicant per 100 gallons of water.

In addition to the saving of labor, thinning the crop over the entire orchard at bloom time should prove to be an advantage to the growth of the tree and the following crop. Bloom sprays will not result in as uniform distribution of fruit as hand thinning but this is not necessary if the set is reduced sufficiently. Two or three fruits situated close together will size uniformly if the branch is not overloaded. In areas where frost injury at blossom time is an annual hazzard, bloom thinning would naturally involve greater risks.

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Effect of Time of Application of Nitrogen on Size and Maturity of Stone Fruits

By E. L. Proebsting, *University of California, Davis, Calif.*

There is a widely held belief among orchardists that an application of nitrogen to stone fruit trees made shortly before picking will increase the size of the fruit. This belief is encouraged by certain fertilizer dealers who urged growers to make an additional amount of nitrogen available to the trees late in the season. Another reason for delaying application of nitrogen in certain cases where heavy set of fruit is common is the idea that supplying this material during the dormant season might further increase the set, with a consequent reduction in size, whereas a delay until after the first drop would help size the fruit. To test the effect of the time of application of the fertilizer, trials have been made on the cherry, apricot, peach, and prune, starting in 1938.

One series of plots was laid out in 1938 in a Paloro peach orchard in Sutter County planted in 1924. Plots of 60 trees each, in duplicate, were treated as follows: $(NH_4)_2SO_4$ the first week in January each year; anhydrous ammonia in the first irrigation, usually early June; anhydrous ammonia in the last irrigation, in September or October; anhydrous ammonia, half in the first and half in the last irrigation; and unfertilized checks. One pound of N was supplied per tree per year. In this, as in all the other trials reported, periodic analyses of leaves were made to be sure of absorption.

The results of this trial have been summarized elsewhere (1), but the pertinent conclusions were that neither size nor maturity were affected by delaying fertilization until mid-season.

In another trial, four plots of ten trees each were selected in a Muir peach orchard planted in 1922 at Davis. One plot was fertilized in February; one in June and one in July, 1943. The latest application was omitted in 1944. One was unfertilized. Each fertilized tree received 1⅓ pounds N in 1943 and 1½ pounds in 1944, the dormant application being $(NH_4)_2SO_4$ and the summer applications being $NaNO_3$. The trees were irrigated immediately after fertilizing in the summer in order to secure rapid absorption. Ten fruits on each tree were tagged for periodic measurement. The growth curves for the two seasons are given, Figs. 1 and 2. There is a slight suggestion that the check plot has made smaller fruit in 1943, but this is not confirmed in 1944. There is no evidence from these data that a delay in the time of application of the nitrogen has affected the character of the growth curves, nor the final size.

The Muirs, although old, showed little evidence of nitrogen starvation. It was thought desirable to supplement the data secured from them with similar data on trees in a low nitrogen status. Accordingly, four plots of Phillips about 20 years old were secured in Sacramento County on a light soil. The same general sequence was used as in the Muirs, and 1½ pounds of N were applied. The set of fruit was heavy, and the thinning proved to be insufficient for good sizing. It is evident

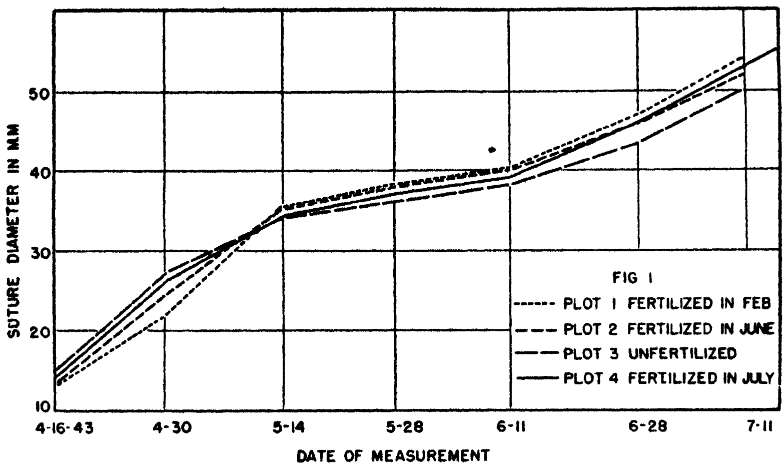

FIG. 1. Growth curves of Muir peaches at Davis, season 1943.

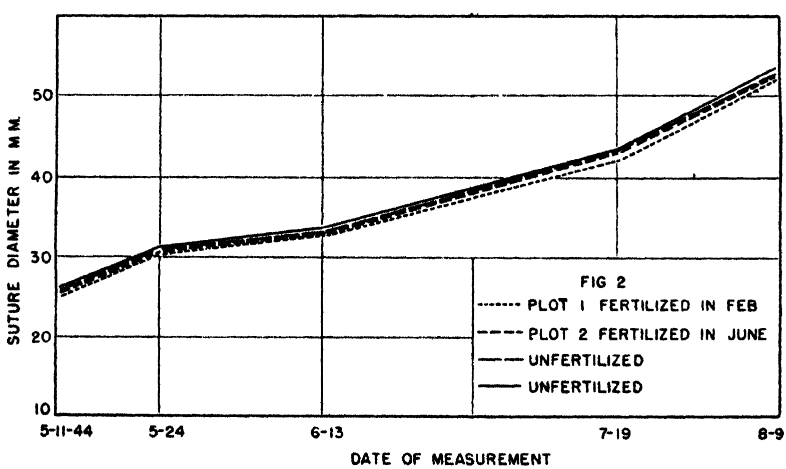

FIG. 2. Growth curves of Muir peaches at Davis, season 1944.

from Fig. 3, showing the growth curves, that even in a low nitrogen situation, addition of this material has not altered the shape of the growth curve.

Cherry plots were established in 1939. The orchard is in an early shipping district in Solano County. The Chapman variety was used. It tends to set heavily and produce small sizes in this district. Time of maturity is of the greatest importance. The rate of application was therefore kept low during the first four years, ½ pound of N (3 pounds of $Ca(NO_3)_2$) per tree being used. The rate was increased to $^5/_6$ pound of N in 1943 and 1944. The trees were small, having been top-worked on Mahaleb in 1931. Three treatments; (a) just

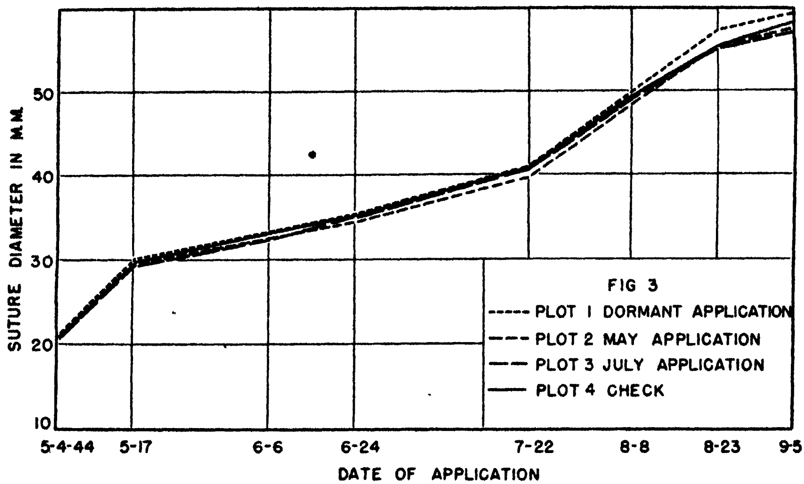

FIG. 3. Growth curves of Phillips peaches in Sacramento County, season 1944.

after blooming, (b) mid-summer, and (c) check, were replicated five times on five-tree plots. The post-harvest treatment was included because a similar timing on apricots in an early shipping district had not delayed maturity, whereas spring application was harmful.

During the first 4 years, little effect of the nitrogen could be observed. Maturity was measured by the per cent of total fruit removed from each tree each picking. In 1939 there seemed to be a slight delay in maturity due to the nitrogen. Only about 25 per cent of the fruit from the fertilized trees were harvested at the first picking compared with about 50 per cent from the unfertilized. About 20 per cent remained for the fourth picking on the fertilized trees compared with 5 per cent from the check. Size, as determined by number per pound, was not affected. In 1940 there was no effect of the fertilizer on maturity or size, and there has not been since. The fertilized trees outyielded the checks about 15 per cent in 1943 and 25 per cent in 1944, the spring application appearing somewhat better than the summer. These two crops were the best of the six recorded. Size and maturity were correlated with amount of crop rather than with treatment. Earlier and larger fruits were obtained with lighter set. The increased yields on the fertilized trees seemed to be associated with a larger bearing surface. Growth, leaf size, and leaf color were better on the fertilized trees.

Prune plots, following the same general plan outlined above for Paloro peaches, were established in 1938 in an orchard in Sutter County. The trees were then 20 years old. Plots consisted of 20 trees each. Maturity was estimated by amount of fruit dropped before picking. Size was determined by grading mechanically a sample of each plot of approximately 500 pounds which had been dehydrated separately. The data indicate a satisfactory correlation between numbers

of fruits per tree and size of fruits, but none with treatment. Neither was there any effect of fertilization on maturity. This orchard, like the Muir peaches, was in a good nitrogen status. It showed response in terms of growth and tree condition, but not in yield.

The apricot seems to be among the most sensitive stone fruits in its response to nitrogen. Preliminary trials on old Royals in low nitrogen status in Yolo County indicated that even ⅓ pound of N as $Ca(NO_3)_2$ in the spring delayed maturity slightly, and $^5/_6$ pound delayed it seriously. The same amounts applied after harvest improved leaf color, postponed leaf fall and gave better developed fruit buds without delaying maturity of the following crop. There seemed to be no tendency toward accumulation over a period of 5 years of annual application of these amounts of N.

Another experiment was started in 1939 on Royal apricots planted in 1918 in the Suisun Valley in Solano County. This is a later district than the one dealt with above and the fruit is either canned or dried. The orchard was in higher nitrogen status than the Yolo orchard. One pound of N per tree was applied in January, March, and July respectively to plots of 11 trees each in triplicate. Yields have been heavy, except in 1943.

There has been an increase in yield from the nitrogen plots compared with the checks. Maturity has been delayed, as measured by per cent of crop removed at each picking. The figures for 1944, which are typical, are as follows: check, 10, 37, 49, and 4; January application, 2, 21, 61, and 15; March, 2, 24, 61, and 13; and July, 3, 25, 61,

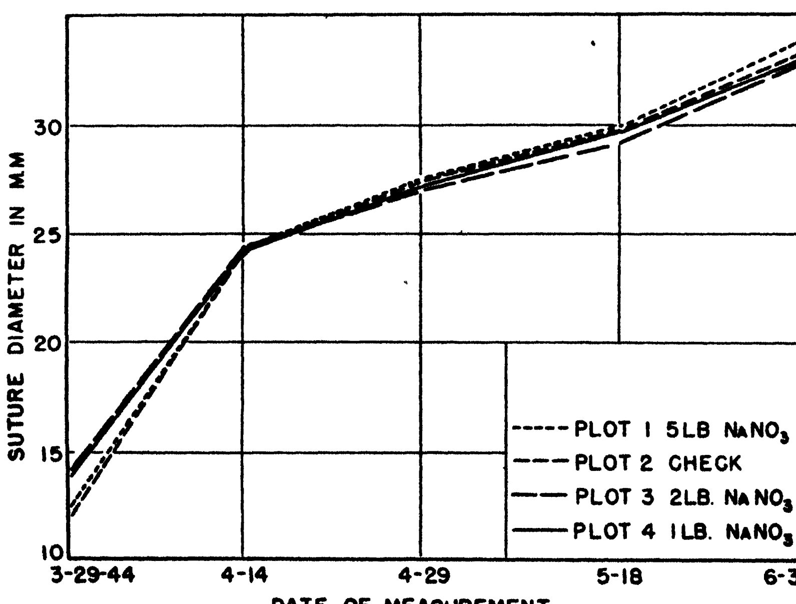

FIG. 4. Growth curves of Royal apricots at Winters, season 1944.

and 11 per cent respectively for the four pickings. Size, determined by calipering random samples at harvest, was not affected.

Growth curves were recorded on another set of Royals planted before 1880 in the Winters section of Solano County. These trees were in rather low nitrogen status, though not so low as the Yolo trees. Plots of ten trees each received $^1/_6$, $^1/_8$, and $^5/_6$ pound of N as $NaNO_3$ on March 28, 1944. At this time the jackets were dropping. The curves, which are average suture diameters of ten tagged fruits per tree, are shown in Fig. 4. It is evident that the curves are essentially the same. The average diameters for the check plot, $33.1 \pm .26$ and the $^5/_6$-pound plot, $33.8 \pm .43$ on the last date of measurement shortly before picking, show that the fertilizer has not affected the size of the fruit.

The experiments recorded above indicate that with four species of stone fruits in widely varying nitrogen status receiving nitrogen at various times of the year, little if any effect on size of fruit has occurred. There may be a distinct effect on time of maturity, which may be very important for early shipping areas. Applications made after harvest seem to have less effect at a given rate of use than when given during the dormant or early spring periods. Yields may be increased, usually by more bearing surface being produced, but size is a function of number of fruits per tree, or per unit of leaf area.

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The Effect of Cultivation, Sod, and Sod Plus Straw Mulch on the Growth and Yield of Peach Trees

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IT is a recognized fact that intensive cultivation of the soil encourages erosion on sloping sites, speeds up the oxidation and disintegration of organic matter, and breaks down the structure of the surface soil. Crop yields may be seriously reduced under such conditions, and, where erosion is serious, the soil may eventually become too depleted for economical production of crops.

At the present time the trend is toward less cultivation in peach orchards in order that some of the above undesirable effects may be avoided. Although a number of experiments (1, 2, 3, 4,) have been reported which indicate that peach trees may be grown in sod, more information is needed before this can be recommended as a commercial practice. The experiment being reported in this paper was designed to compare the effect of sod, sod plus straw mulch, and cultivation with cover crops on the growth and yield of peach trees in Ohio.

MATERIALS AND METHODS

The South Haven peach trees which were studied in this experiment were planted in the spring of 1935 on Wooster silt loam soil. Six different soil management systems were followed: (a) bluegrass sod, (b) bluegrass sod plus straw mulch under the branches of the trees, (c) spring cultivation followed by a summer cover crop of soybeans and a winter cover of rye, (d) same as treatment (c) except 16 tons per acre of manure were applied each spring, (e) same as treatment (c) except 14 tons per acre of chopped corn stover were applied each spring and disced into the soil, (f) spring cultivation followed by a summer cover crop of Sudan grass and a winter cover of rye. The entire area of the orchard was fertilized each spring by applying a broadcast application of 400 pounds per acre of ammonium sulphate. All trees received similar pruning and spraying treatment.

The trees in the cultivation-soybean-rye treatment were located in a poorly drained area of the orchard. This resulted in low vigor and irregular growth and, therefore, this treatment has been disregarded in this report.

All cultivated plots were disked in the middle of May and once or twice more until early July when the summer cover crop was planted. The summer cover crop was disked down in early October and the winter cover of rye was sown. In all cultivation operations an attempt was made to avoid excess chopping and mechanical disintegration of the organic matter. The resulting trashy condition helps to prevent soil erosion.

Results and Discussion

During the first 10 years of this orchard (through 1944) the different systems of culture have had no significant effect on blooming date, ripening date, quality of fruit, color of fruit, or winter injury of wood or buds. During 1941, 1943, and 1944, leaves from the various plots were collected for surface-area measurements. The results showed no definite correlation between the different soil-management treatments and leaf area.

The bar graphs of Fig. 1 illustrate the yield, tree growth, and soil organic matter data which were collected during recent years. The average trunk circumference of trees in the sod plots was smaller than in the other plots. During the early bearing years these smaller trees were definitely less productive than the larger trees in the cultivated sections of the orchard, as is illustrated by the yield data for 1941 and 1942. During recent years the trees in sod have produced in a very satisfactory manner as indicated by the yield data of 1943 and 1944. In each case, the yields for 2 years were averaged to minimize seasonal fluctuations. It should also be noted that as the trees in the sod plus

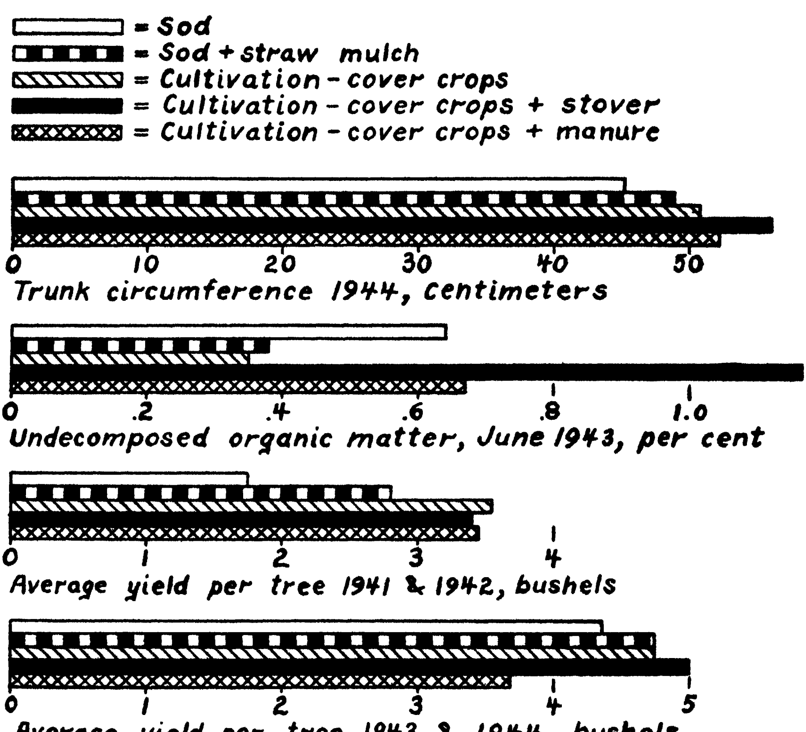

FIG. 1. Undecomposed organic matter in silt loam soil, and trunk circumference and yield of peach trees growing under different cultural systems on this soil.

straw mulch treatment became older they likewise produced better in proportion than when they were younger. These results are in agreement with those of Olney and Armstrong (6) in Kentucky, who found that older peach trees grew better in sod than did young trees.

Undecomposed organic matter was determined by the method of McCalla, *et al.* (5), in which particles above 2.0 mm in size were removed by dry screening and particles from 0.5 to 2.0 mm in size were removed by wet screening of the dispersed soil.

The graph of Fig. 1 illustrated that the undecomposed organic matter content of the soil was highest in the cultivation plus corn stover treatment, whereas the sod and cultivation plus manure had a medium amount, and the cultivation-cover crop and sod plus mulch plots had the lowest. It should be noted that there is no correlation between the per cent of undecomposed organic matter and tree growth or yield. In other words, it would seem that on the silt loam soil used in this experiment the amount of undecomposed organic matter in the soil was a minor factor in influencing the growth or yield of peaches. Similar results were obtained when the total organic matter was determined by the chromic acid method of Schollenberger (7).

The low content of undecomposed organic matter in the soil under the mulch was due to the fact that this soil contained no grass roots and all of the coarse organic matter remained on the surfaces as a mulch and was not incorporated into the soil by discing.

Soil moisture was determined during several seasons. During the growing season the soil under the sod was frequently dryer than in the other cultural treatments but at no time did it reach the wilting point. It would seem, therefore, that soil moisture was not a limiting factor in the production of peaches on the silt loam soil used in this experiment.

Total soil nitrogen and nitrates were determined during several seasons. The results were somewhat variable but they indicate that the slower growth of young peach trees in sod is due to a lack of available nitrogen. Work is being carried on to secure additional information on this phase of the problem.

Summary

The most important points brought out in the experiment reported here are:

1. The yield of peaches is proportional to the size of the trees (as indicated by trunk circumference measurements), unless affected by such hazards as spring frosts or insect and disease damage.
2. Tree growth and yield of fruit were not proportional to total soil organic matter, undecomposed organic matter, or soil moisture in the Wooster silt loam soil upon which this experiment was conducted.
3. Although more evidence is needed before a definite conclusion can be drawn, the principal factor limiting the growth of trees in the sod plots seemed to be a lack of available nitrogen.
4. The different cultural treatments had no effect on blooming date, ripening date, quality or color of fruit, leaf size, or susceptibility to winter injury of wood or buds.

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Some Effects of Irrigation on the Interrelations of Growth, Yields, and Drying Ratios of French Prunes

By A. H. HENDRICKSON and F. J. VEIHMEYER, *University of California, Davis, Calif.*

THE determination of the drying ratio, or the number of pounds of fresh fruit required to make one pound dried, has been a part of our experiments on the irrigation of French prunes. We have shown in previous reports (1, 2) to the Society that the average drying ratios of the fruit from the irrigated plots were slightly higher than those from the plots not receiving irrigation when the fruit was on the trees. While we concluded that the differences were not significant, our conclusions were based on only 3 years' results in the first report. We also showed that on trees of comparable size, whose crops were caused to differ by thinning, the apparent drying ratios were correlated with yields. At the end of an additional five years, these small but significant differences were found to persist as shown in Table I. This report is an effort to further evaluate the relation between the apparent drying ratios and the relative yields and growth of the trees during the 12 years of differential irrigation treatment.

TABLE I—AVERAGE DRYING RATIOS OF FRENCH PRUNES FROM IRRIGATED AND UNIRRIGATED PLOTS*

1933	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944
Irrigated											
2.45	1.73	2.60	2.06	2.85	2.72	2.61	2.85	2.69	2.94	3.12	2.67
Unirrigated											
2.30	1.81	2.36	1.99	2.69	2.73	2.40	2.67	2.77	2.91	2.87	2.53

*Odds by student's method that the 12-year average drying ratios are significantly different 160:1.

At the beginning of the experiment, the plots were laid out in such a way that the trees were as nearly equal in size as possible. The average cross-section areas of the tree trunks in 1932 in the plots that were to receive irrigation were slightly smaller than those that were, thereafter, to receive no water by irrigation while the fruit was on the trees. In 1933 the irrigated trees were divided into three treatments, varying as to amount of water and time of application, but are all grouped together in the results presented in this paper. In other words, this report deals with certain responses by trees that received some water during the growing season, compared with others that were not irrigated while the crop was on the trees and were without readily available soil moisture after the early part of July. At the end of 12 years the trees in the irrigated plots were larger in trunk cross-section area than those that were unirrigated, as shown in Table II. The tops of the irrigated trees were noticeably larger than the unirrigated ones, and unpublished results show that they produced more weight and

TABLE II—AVERAGE CROSS-SECTION AREAS OF TRUNKS OF FRENCH PRUNE TREES

Treatment	1932 (Sq Cms)	1944 (Sq Cms)	Gain (Sq Cms)
Irrigated	258.7	496.9	238.2
Unirrigated	270.7	467.8	197.1

greater numbers of fruits than the unirrigated ones. Because the irrigated trees grew more than the unirrigated ones and had a greater bearing area, it is evident that yield records alone in terms of weight or numbers of fruits per tree would not be satisfactory in evaluating the relation between the drying ratios and yields. It seemed desirable, therefore, to study the relation of yields to bearing areas of the trees. For example, approximately equal crops as far as pounds or number of fruit were concerned might prove to be a moderate crop for the irrigated trees but a very large one for the smaller, unirrigated trees. In this connection it is well to point out that French prunes do not drop badly and are not thinned ordinarily; hence, when the crop is set, it remains on the tree until harvest.

An exact measure of the relative crop of a tree may be hard to find but one frequently used has been the number of leaves or the leaf area per fruit. We have sought a measure of relative yields that would be applicable to the large number of trees involved and to the data of the earlier years of the investigation. The measure used has been the weight or numbers of fruit per square centimeter of cross-section area of the trunk, or per square centimeter of annual increment of growth. The ratios of yields to cross-section area in 1932 before differential treatment started were nearly equal, being .632 for the plots that were to be irrigated and .602 for the unirrigated ones.

The results presented in Table III show that, on the whole, the irrigated trees produce more fruit per unit of cross section area than the unirrigated ones. The results for 1934 and 1941 are omitted from the table because of the severe cracking and premature dropping of the cracked prunes and complete records of weights and numbers could

TABLE III—YIELDS OF PRUNES PER SQ. CM. OF TRUNK CROSS-SECTION AREA*

Year	Ratios of Yields in Pounds to Trunk Cross-Section		Ratios of Numbers of Prunes to Trunk Cross-Section	
	Irrigated	Unirrigated	Irrigated	Unirrigated
1932**	0.632	0.602	—	—
1933	0.940	0.601	244	237
1935	0.414	0.179	81	47
1936†	0.321	0.214	71	57
1937	0.974	0.832	193	189
1938	0.678	0.511	110	88
1939	0.869	0.599	158	121
1940	0.749	0.520	114	101
1942	0.599	0.475	97	76
1943	0.947	0.731	199	159
1944	0.503	0.399	88	91

*Many prunes cracked and dropped early in 1934 and 1941, making it impossible to secure complete yield records.
**Before differential irrigation treatment.
†Frost in 1936.

not be obtained. The year 1933 is interesting, due to the fact that it was the first year of differential irrigation treatment. All trees set approximately 8400 fruits per tree, but the irrigated ones matured 262 pounds per tree while the unirrigated ones produced only 172 pounds. There was a considerable difference between the irrigated and unirrigated trees in the ratios of yields to cross-section areas but not of numbers to cross-section areas. This difference was probably due to the fact that the unirrigated trees exhausted the readily available soil-moisture before the fruits had attained full size, and the prunes remained small. Exhaustion of readily available moisture apparently did not cause any dropping of the fruit and the ratios of cross-section areas to numbers were approximately equal.

After 1933 the ratios were generally lower in the case of the unirrigated trees than with the irrigated ones, showing that the unirrigated trees set less fruit per unit of cross-section area than the irrigated ones. Apparently, the lack of readily available soil moisture after about July 1 had a deleterious effect on fruit setting. The cause of the reversal of ratios of numbers to cross-section areas in 1944 is unknown.

The next step was to see if there was any correlation between the ratios of weights or numbers to cross-section areas, and the drying ratios. The results are given in Table IV. In general, there is fairly good correlation. The correlations dealing with the relationships of weights and drying ratios in most cases are a little higher than those dealing with numbers.

TABLE IV—Correlations Between Drying Ratios of Prunes and the Ratios of Yields or Numbers to Cross-Section Areas of Trunks in All Plots

Year	Yields in Pounds Per Sq Cm of Trunk Trunk Cross-Section Areas to Drying Ratios	Numbers of Fruits Per Sq Cm of Trunk Cross-Section Areas to Drying Ratios
	r	r
1933	0 786 ± .061**	0.332 ± .147
1935	0.550 ± .111	0.459 ± .125
1936	0.577 ± .106	0 458 ± .126
1937	0.780 ± .062	0.513 ± .133
1938	0.690 ± .083	0.693 ± .098
1939	0.705 ± .080	0.546 ± .111
1940	0.659 ± .090	0.502 ± .119
1942*	0.224 ± .151	0.294 ± .147
1943	0.875 ± .037	0.689 ± .083
1944	0.701 ± .081	0.430 ± .129

*Entire crop not harvested.
**Probable error.

The results for 1934 and 1941 were omitted because of severe cracking and premature dropping of the fruit. Some early dropping and difficulties in securing labor for harvest in 1942 resulted in the loss of some fruit and probably account for the low correlations found that year.

Inasmuch as the unirrigated trees rather consistently had a lower drying ratio and a smaller ratio of yields to cross section area than the irrigated ones (Tables I and III), it might be argued that correlation would necessarily follow when the two groups were used in the same calculation as was done in Table IV. The data, therefore, were exam-

ined further to see if correlation between yields and drying ratios existed within each group. In these studies, the annual increments of cross-section area were used, as they show marked responses to heavy or light crops that may be obscured when total cross-section areas alone are used, especially with large trees. The results are given in Table V. These results indicate a fair degree of correlation in general,

TABLE V—Correlation Between Drying Ratios of Prunes and the Ratios of Yields or Numbers to Current Annual Increments in Cross-Section Areas of Trunks

Year	Yields in Pounds Per Sq Cms Increment of Trunk Cross-Section Areas to Drying Ratios r		Numbers of Prunes Per Sq Cms Increment of Trunk Cross-Section Areas to Drying Ratios r	
	Irrigated	Unirrigated	Irrigated	Unirrigated
1933	0.498 ± .153	−0.197 ± .245	0.400 ± 171	−0.355 ± .223
1935	−0.422 ± .167	−0.687 ± .135	−0.306 ± .184	−0.381 ± .218
1936	0.501 ± .152	−0.143 ± .250	−0.487 ± .155	−0.566 ± .173
1937	0.623 ± .125	0.729 ± .119	0.553 ± .141	0.705 ± .128
1938	0.699 ± .104	0.760 ± .108	0 559 ± .140	0.938 ± .031
1939	0.633 ± .128	0.593 ± .165	0.109 ± .211	0.405 ± .213
1940	0.602 ± .130	0.580 ± .169	0.413 ± .169	0.615 ± .158
1942	0.558 ± .140	0 —	0.741 ± .092	−0.272 ± .236
1943	0.540 ± .144	0.364 ± .221	0 507 ± .151	0.074 ± .253
1944	0.761 ± .186	0.655 ± .146	0.633 ± .123	0.730 ± .119

and they also indicate a marked response to factors, such as insect damage, with resulting low or negative correlations. The results prior to 1936 show the results when the mealy plum aphids were not satisfactorily controlled. Frost damage occurred in 1936, and although the aphids were controlled, the correlations were largely negative. Since 1936 the results, on the whole, show fair correlation, one exception being in 1942 when a new but ineffective spray was used in an effort to control the aphids.

Summary

The results presented seem to show that French prune trees at Davis, California, when left without water other than that from the winter rains through the season when the fruit is on the tree, tend to set smaller crops per unit of cross-section area of trunks or of annual increment and have slightly lower drying ratios than do trees that are supplied with some water. If the trunk cross-section area may be used as a measure of leaf area, the fruits on these unirrigated trees have a larger leaf area per prune than on the irrigated trees. If this is true, the increased leaf area may help to explain the slightly lower drying ratio frequently found with prunes from the unirrigated plots.

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Cracking and Decay of Bing Cherries as Related to the Presence of Moisture on the Surface of the Fruit

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THE presence of free moisture on the surface of the fruit has always been a matter of great concern to the grower and shipper of sweet cherries. Moisture from rain at harvest can cause sufficient cracking of the fruit to result in large financial losses. In the form of condensed water vapor on the surface of stored cherries as a result of temperature changes (sweating), moisture is popularily believed to increase decay. The hesitancy of shippers to use hydrocooling for the rapid removal of field heat from sweet cherries is also based largely on the assumption that it may increase decay.

The most common type of cracking of cherries is caused by the osmotic absorption of water through the skin of the fruit (3). Verner (2) found that calcium sprays reduced cracking materially but left conspicuous residues detrimental to the appearance of the fruit. Gerhardt and Hukill (1) demonstrated that sweet cherries can be hydrocooled without injury, by using ice and water at 32 degrees F to reduce the temperature of the fruit from 65 to 33.7 degrees in 7 minutes.

Weather conditions during June, 1944, precluded studying the incidence of cracking of cherries in relation to the time of picking following a single rain. This paper, however, presents certain studies on the cracking and "healing" of Bing cherries as influenced by the cumulative effect of successive rains. It presents results of experiments on the relation between sweating of the stored fruit and decay, and includes further tests with hydrocooling of Bing cherries.

MATERIAL AND METHODS

In the studies on cracking at harvest, approximately 20 pounds of fruit were picked from a vigorous, medium-bearing, 15-year-old Bing cherry tree between 8:00 and 11:00 a.m. on successive days following rain. The fruit from each picking was thoroughly composited and separated into triplicate samples of 2.5 kg prior to examination for its degree of cracking. Small, shallow checks in the skin around the stem and stylar ends were classified as slight cracks; large splits in the skin, which usually occurred on the shoulder and stylar surfaces, were recorded as severe cracks. Fruits with severe cracks are commercial culls. After storage at 40 degrees F for 10 days in a relative humidity of 85 per cent, these samples were again examined for decay and for loss in weight.

In the studies on moisture condensation (sweating), 100 pounds of rain-damaged commercial fruit was used to insure sufficient decay for experimental purposes. After being carefully sorted to remove all visible decay, culls from bird injury, and rain splits ¼-inch or larger, the fruit was thoroughly composited and separated into five replicate

samples of 2.5 kg for each storage and handling treatment. In connection with the sweating studies, spore germination tests were also made using pure cultures of six of the more important fungi associated with decay in sweet cherries. The species employed were as follows: *Alternaria* sp., *Botrytis cinerea* Pers., *Cladosporium herbarum* Fr. *Pencillium expansum* Lk. emend. Thom, *Rhizopus* sp., and *Sclerotinia fructicola* (Wint.) Rehm. Spores from each of the test organisms were suspended in 10 ml of distilled water in Erlenmeyer flasks. A small cube of sterile apple tissue was placed in each flask to provide the necessary stimulus for spore germination. The suspensions were stored immediately at various temperatures and small portions were removed at frequent intervals for microscopic observation of spore germination.

For the hydrocooling work, 50 pounds of carefully selected sound Bing cherries were harvested at each of two maturities. Duplicate 1 kg samples of the composited fruit of each maturity were placed in wire baskets and immersed in a 50-gallon tank of ice and water at 32 degrees F for various lengths of time. After immersion and examination for cracking, one lot was dried immediately in air at 32 degrees. Both the wet and the dry samples were then stored at 40 degrees for 10 days, after which they were examined for decay.

Results

Cracking of Bing Cherries:—In order to minimize losses from rain damage, many growers shake the water from the foliage and fruit of cherry trees immediately following showers. It is also customary to delay harvest several days following rain in the belief that cracked fruits will "heal over" and thereby become less susceptible to decay. Under the conditions of intermittent rainfall and high humidity between showers encountered in 1944, as shown in Table I, a delay in picking was of no value in reducing losses from rain damage.

TABLE I—Cracking of Bing Cherries at Harvest in Relation to the Cumulative Effect of Successive Rains, 1944

Picked		Rain			Cracked Fruit		
Date and Time	Period After First Rain (Hours)	Amount (Inches)	Duration (Hours)	Time	Slight (Mean Per Cent)*	Severe (Mean Per Cent)*	Total (Mean Per Cent)**
Jun 16 10:30 a.m.	0.5	1.08	16.5	4:00 a.m.–10:00 a.m. 2:30 p.m.–12:00 m.	45.7	3.5	49.2±1.41
Jun 17 8:30 a.m.	22	0.10	1	12:00 m.–1:00 a.m.	29.5	41.2	70.7±1.69
Jun 18 9:00 a.m.	48	0.12	1.5	4:00 a.m.– 5.00 a.m. 2:00 p.m.– 2:30 p.m.	35.0	39.6	74.7±0.74
Jun 19 8:30 a.m.	72	0.10	1	5:00 p.m.– 6:00 p.m.	37.7	40.3	78.0±0.46
Jun 20	—	None	—	—	—	—	—
Jun 21 8:30 a.m.	120	None	—	—	41.9	35.1	76.9±0.53

*Average of three replicate samples.

**Standard error of the mean calculated from: $\sqrt{\frac{\Sigma d^2}{n(n-1)}}$ Differences in the mean per cent of total cracked fruit between successive pickings are statistically significant (odds >19:1) in all except the last picking.

Data in Table I show that the severity and total amount of cracking in Bing cherries was least when harvest occurred within half an hour after the first rain of June 16. The second rain of 9.5 hours duration on the same day was very damaging to the fruit. Both the severity and the total amount of cracking had greatly increased by the time of the second picking, 22 and 8.5 hours after the first and second rains, respectively. With the exception of the last shower on June 19, each successive rain caused a significant increase in the total amount of cracking in Bing cherries harvested at intervals from June 16 to 21, inclusive. However, there was little change in the amount of severely cracked fruit (commercial culls) after the second picking. By this time, evidently, the osmotic relationships within the fruit had become stabilized to the extent that all fruits susceptible to severe cracking had ruptured.

Microscopic examination of the "healing" of cracked cherries showed the process to be largely a drying out of the exposed tissue and not a true healing over by the production of cork cells. It was also observed that large cracks were seldom sufficiently desiccated to insure protection against fungous infection. Following the rains of June 16 cracked fruit started to "heal" quite well by the next afternoon but the morning and afternoon rains of June 18, together with the prevailing high humidity of the day, caused a water-logging of the partly "healed" fruit, which continued until after the shower on June 19. In contrast, the slight cracks on the shoulder tip, and side of the fruit harvested on June 21 were well "healed" 38.5 hours after the last rain. No "healing" was observed in the fruits stored at 40 degrees F for 10 days.

Data on the amount of decay and loss in weight of Bing cherries from the various pickings of rain-damaged fruit are shown in Table II. The amount of decay and the loss in weight varied directly with the intensity of cracking. Decay also became more prevalent with each successive picking.

Moisture Condensation (Sweating) of Bing Cherries:—Most warehousemen and shippers are firm in a belief that the condensation of moisture on the surface of sweet cherries moved from a cold to warm atmosphere favors the development of decay. Much of their commercial handling and storage program is guided by a desire to prevent this "sweating" of the fruit. Because of the importance they attach to this objective many operators failed to appreciate fully the importance of low storage temperature in delaying the germination of fungus spores and the subsequent development of decay.

The studies on sweating of Bing cherries in relation to decay are summarized in Table III, where rain-damaged fruit was purposely used to insure a high percentage of natural infection.

These data show that heavily sweated fruit held at 40 degrees F did not show a statistically significant increase in decay over comparable lots of unsweated fruit stored at the same temperature. Similar results were obtained when the same samples were held for an additional 2 days at 65 degrees. Table III also shows that significantly more decay occurred in non-sweated fruit held at 50 degrees than in comparable lots of heavily sweated fruit at 40 degrees.

TABLE II—DECAY AND LOSS IN WEIGHT IN BING CHERRIES DURING STORAGE WHEN HARVESTED AT INTERVALS FOLLOWING SUCCESSIVE RAINS, 1944

Treatment	Kind of Fruit	1st Picking Jun 16 (Mean Per Cent)*	2nd Picking Jun 17 (Mean Per Cent)	3rd Picking Jun 18 (Mean Per Cent)	4th Picking Jun 19 (Mean Per Cent)	5th Picking Jun 31 (Mean Per Cent)
		Decay				
Immediate storage at 40 degrees F for 10 days	Severely cracked	16.9	58.6	89.3	94.0	100.0
	Slightly cracked	3.2	15 6	35.5	38.6	55.7
	Sound	1.4	6 6	12.8	17.1	20.4
	Mean**	2.8 ±0.30†	29.9 ±1.48	50.6 ±2.08	55.8 ±1.36	62.6 ±1.24
Immediate storage at 40 degrees for 10 days and ripening at 65 degrees for 2 days	Severely cracked	32.3	82.8	97.0	98.8	100.0
	Slightly cracked	17.2	28.9	49.8	55.1	63.7
	Sound	8 5	17.7	23.6	25.6	26 4
	Mean**	13.2 ±0.17†	47.4 ±2.02	61.5 ±1.38	65.9 ±0.82	67.4 ±0.73
		Loss in Weight				
Immediate storage at 40 degrees for 10 days	Severely cracked	14 7	7.7	5.5	5 8	7.1
	Slightly cracked	5.3	3.8	2.5	3 0	5.2
	Sound	1.6	2.3	2.9	3.6	5 4
	Mean**	4.2	4.9	3.8	4.3	5.8

*Average of three replicate samples of 2.5 kg each.
**Average based on the total number of fruits in each picking.
†Standard error of the mean calculated from $\sqrt{\frac{\Sigma d^2}{n(n-1)}}$

TABLE III—THE INFLUENCE OF SURFACE MOISTURE (SWEATING) ON RAIN-DAMAGED BING CHERRIES IN RELATION TO THE DEVELOPMENT OF DECAY IN STORAGE, 1944

Treatment	Decay: After 10 Days Storage at 40 degrees F (Mean Per Cent)*	Decay: After Post-storage Ripening 2 days at 65 degrees F (Mean Per Cent)
No Sweating		
Continuous storage at 40 degrees for 10 days	26.3 ± 0.99**	37.5 ± 0.92 **
Held for 2 days at 50 degrees followed by 8 days storage at 40 degrees	36.2 ± 0.88	47.8 ± 0.80
Heavily Sweated		
Held for 2 days at 40 degrees, removed to 65 degrees for 2 hours, then stored 8 days at 40 degrees	27.8 ± 0.64	39.5 ± 0.74

*Average of five replicate samples of 1 kg each.
**Standard error of mean calculated from $\sqrt{\frac{\Sigma d^2}{}}$

Since condensation of moisture on the surface of sweet cherries at 40 degrees F failed to increase decay, it seemed probable that the sweating did not persist long enough to influence spore germination.

Experiments were then conducted to determine the duration of sweating on moisture-laden fruit packed in standard 17-pound cherry lugs held at 40 degrees in a relative humidity of 85 per cent, with an air movement of 75 to 100 ft. per minute. An occasional droplet of moisture was found on the fruit in the center of the packages after 6 hours' storage, only a trace of free moisture after 9 hours, and none after 10 hours.

Spore Germination Studies:—Along with the observations on the persistence of sweating, studies were also made on the rate of germination of the spores of the more common fungi causing decay of sweet cherry fruits. The germination rates of the spores of these molds at four different temperatures are shown in Fig. 1. These data indicate that,

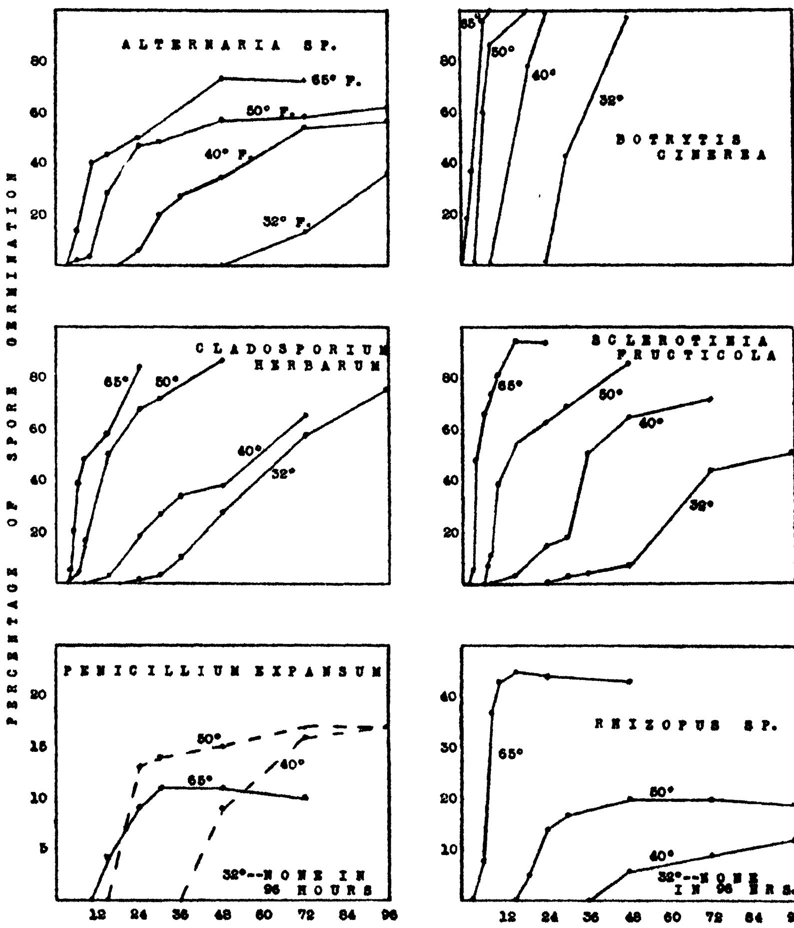

FIG. 1. The effect of temperature on the rate of germination of the spores of several fungi causing decay in sweet cherries.

in general, temperatures of 40 degrees and 32 degrees F exerted a marked inhibitory effect on germination. At 40 degrees only Botyrtis spores showed a germination of 1 per cent in 8 hours, the spores of the other five organisms requiring from 12 to 36 hours for germination at this temperature.

These studies show that the time required for spore germination is usually longer than the interval during which the condensed moisture remains on the fruit, and this probably explains why no relation was found between sweating and decay (Table III).

Hydrocooling of Bing Cherries:—The field heat in many commercially grown vegetables is often removed by immersing the product in iced water prior to shipment. Much of the Washington asparagus crop is cooled by a 9-minute exposure to a spray of iced water. This procedure has recently been used successfully in a limited way for cooling commercial lots of sweet cherries. It was demonstrated in an earlier report (1) that the pulp temperature of cherries could be reduced from 65 degrees F to 33.7 degrees in 7 minutes by immersing them in iced water.

Results of further studies on the hydrocooling of sound, non-rain-damaged Bing cherries show the relation of period of immersion, maturity of the fruit, and presence of moisture when packed, to the subsequent development of cracking and decay (Table IV). These data show that fruits of the earlier maturity were less susceptible to cracking and decay than those that were riper. As far as cracking and decay in storage are concerned, it apparently made little difference whether the hydrocooled fruit was packaged wet or dry. From the standpoint of

TABLE IV—RELATION OF HYDROCOOLING AT 32 DEGREES F TO CRACKING AND TO THE DEVELOPMENT OF DECAY IN BING CHERRIES, 1944

Treatment	Type of Pack	Cracked Fruit** (Per Cent)	Decay	
			10 Days at 40 Degrees F (Per Cent)	Plus 2 Days at 65 Degrees F (Per Cent)
		Early Maturity—Pie Cherry Red		
Check*	Dry	0.0	0.2	0.8
Hydrocooled 32 degrees	Wet	0.0	0.0	1.3
for 30 min	Dry	0.0	0.5	1.9
Hydrocooled 32 degrees	Wet	0.0	0.6	2.1
for 60 min	Dry	0.0	0.5	1.1
Hydrocooled 32 degrees	Wet	2.9	0.6	7.0
for 6 hours	Dry	4.6	2.1	7.7
Hydrocooled 32 degrees	Wet	44.9	4.8	29.0
for 14 hours	Dry	45.4	3.1	27.4
		Late Maturity—Mahogany Red		
Check*	Dry	0.0	2.7	4.3
Hydrocooled 32 degrees	Wet	0.0	2.1	7.3
for 15 min	Dry	0.0	4.5	6.2
Hydrocooled 32 degrees	Wet	0.0	1.8	8.0
for 30 min	Dry	0.0	3.1	7.7
Hydrocooled 32 degrees	Wet	9.6	1.0	13.0
for 6 hours	Dry	6.0	3.7	14.1
Hydrocooled 32 degrees	Wet	66.1	6.0	55.9
for 14 hours	Dry	63.5	8.2	51.1

*Held continuously in air at 40 degrees F.
**After storage at 40 degrees F for 10 days.

commercial practicability the period of hydrocooling could rarely be longer than 15 minutes but data in Table IV show that Bing cherries can tolerate longer periods of hydrocooling without danger of injury to the fruit.

Verner and Blodgett (3) found in immersion tests that the rate of cracking of Bing cherries increased with increasing temperature. Their observation is confirmed by the data in Fig. 2 which summarizes a study of the hydrocooling of Bing cherries at temperatures ranging from 40 degrees to 75 degrees F.

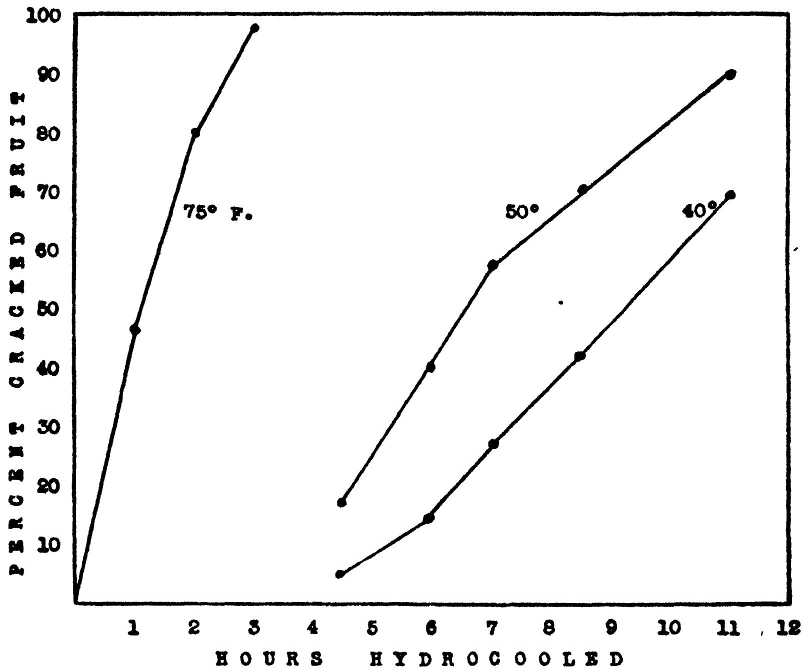

FIG. 2. The rate of cracking of Bing cherries when hydrocooled at different temperatures.

Where reduction of decay is so vital in such a perishable commodity as sweet cherries, storage temperatures of 32 degrees to 36 degrees F should be employed. When cold storage facilities are not available or when the rapid removal of field heat is desired, information presented in this paper shows that Bing cherries may be hydrocooled 15 to 30 minutes at 32 degrees without cracking or appreciable increase in decay. The stem greenness and general appearance of the hydrocooled fruit were fully equal but not superior to that cooled in air at 32 degrees at a relative humidity of 85 per cent.

Summary

The cumulative effect of a succession of rains over a 4-day period at harvest caused an increasingly larger amount of cracking of Bing

cherries the longer the fruit remained on the tree. The increase in decay and the loss in weight of the rain-damaged fruit after picking were directly correlated with the intensity of cracking and the time of harvest. No "healing" of the injured fruit occurred during storage at 40 degrees F.

The temporary condensation of moisture on the surface of Bing cherries held at 40 degrees F did not cause an increase in the amount of decay but short periods at 50 degrees without sweating increased decay significantly. Failure of sweating to stimulate decay is explained by the fact that the film of moisture on the surface of the fruit was not retained long enough to permit germination of mold spores at that temperature.

Hydrocooling of Bing cherries with iced water at 32 degrees F for as long as 30 minutes did not produce injury to the fruit; its appearance was comparable to that of fruit cooled in air at 32 degrees with a relative humidity of 85 per cent.

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Differences in After-Ripening Requirements of Several Sources and Varieties of Peach Seed[1]

By R. F. Carlson and H. B. Tukey, *New York State Agricultural Experiment Station, Geneva, N. Y.*

The standard recommendation for the after-ripening of peach seed is 10 to 12 weeks at 3 to 5 degrees C (37 to 41 degrees F) (3, 6). Nurserymen commonly plant seed in the fall of the year so that after-ripening occurs before spring. When fall planting is not possible, the seed is "stratified" for after-ripening in damp sand or peat moss and held at about 40 degrees F, the stratification being begun at a time estimated to complete after-ripening for spring planting.

The recommended period of 10 to 12 weeks does not always result in satisfactory germination and stands of seedlings. Nurserymen find that in some seasons and with some varieties the required period of after-ripening may be more or less than 10 weeks. Crocker (1) gives 35 to 60 days at 45 degrees F (7 degrees C) as the after-ripening requirement for peach seed removed from the stony pericarp, and 60 to 100 days when enclosed in the stony pericarp. Haut (3) has reported 44 per cent germination of Late Crawford peach seed after only 25 days of after-ripening at 3 degrees C (37 degrees F). Crocker and Barton (2) found that peach seed germinated well following an after-ripening period of 3½ months at 5 to 10 degrees C (41 to 50 degrees F), but that 1 degree C was a less favorable temperature.

The experiments reported in this paper were undertaken to determine what degree of variation exists in the after-ripening requirements of different sources and varieties of peach seed.

Materials and Methods

Seed from nine varieties of peaches were collected from the Experiment Station orchard in the fall of 1944 as follows: Belle, Champion, McAllister, Muir, October, Elberta, USSR 106, USSR 557, and Ward Late. A tenth variety, Lovell, was secured from California.

Seventy to one hundred seeds of each variety were used in the tests. The pits were cracked with a nut cracker and only the seeds were used. This procedure was adopted in order to insure uniformity, since germination may be delayed by presence of the stony pericarp (2, 3, 6). The seeds were after-ripened in moist peat moss in a controlled refrigerator at 34 to 37 degrees F (1 to 3 degrees C). They were packed in layers of ten with peat moss between each layer, so as to provide uniform contact with the moist moss. The moss was moistened until water could be squeezed from it. The jars were fitted loosely with glass covers so as to provide aeration. Five to ten seeds were removed from each lot at weekly intervals for 12 weeks and germinated in petri dishes lined with moistened filter paper at a temperature of 60 to 75 degrees F.

[1]Journal article No. 626 of the New York State Agricultural Experiment Station.

In addition to these laboratory tests, the germination of four commercial lots of Lovell seed from four different sources were observed in a commercial nursery planting at Geneva, New York. They were planted in the field on September 20. Samples were dug, the pits cracked, and the seed germinated in the laboratory on December 5.

Results

Laboratory Tests:—Seeds that germinated did so within 48 hours after being placed in petri dishes on moist filter paper. The percentage germination for the different varieties for the different periods of after-ripening are given in Table I.

TABLE I—Percentage Germination of Ten Varieties of Peach Seed After-Ripened at 1 to 3 Degrees C for 3 to 12 Weeks*

Variety	Weeks of After-Ripening (Percentage Germination)									
	3	4	5	6	7	8	9	10	11	12
Belle	40	20	30	40	30	40	40	40	60	80
Champion	40	70	70	80	80	80	80	80	80	80
Lovell	0	0	40	40	60	60	60	60	80	80
McAllister	80	60	60	60	70	80	80	80	80	90
Muir	0	0	0	0	0	0	0	0	40	40
October Elberta	40	20	60	80	80	60	60	80	80	100
Salwey	60	90	70	60	90	90	90	100	100	100
U.S.S.R. 106	40	20	60	40	40	80	80	80	80	80
U.S.S.R. 557	0	0	20	10	20	60	60	60	60	60
Ward Late	20	10	40	80	80	80	100	100	100	100

*For comparison with these figures, the percentage germination shown by the excised-embryo method, which usually runs a little higher than after-ripening percentages, averaged 90 to 100 for all varieties used.

Of the 10 lots, 7 varieties germinated to some degree following only 3 weeks of after-ripening; 3 varieties showed no germination until after 5 weeks of after-ripening.

The maximum percentage germination was reached after a shorter period of after-ripening with some varieties than with others. The Salwey variety reached near maximum germination (90 per cent) after 4 to 7 weeks of after-ripening, as compared with 100 per cent germination after 10 to 12 weeks; and the McAllister and Champion varieties reached near maximum germination after 3 and 6 weeks of after-ripening, respectively. On the other hand, the variety USSR 557 germinated only 20 per cent after 7 weeks of after-ripening, and the Muir variety showed no germination until after 11 weeks of after-ripening. In all but one instance maximum germination was secured between 10 and 12 weeks. The exception was the Muir variety.

No observations were made of growth characters of seedlings which developed from seed after-ripened for various intervals of time. In another paper (9) it has been shown that after-ripening of the seed to the minimum for germination does not necessarily bring about "normal" vigorous plant development. If the after-ripening period is short, the seed may germinate but the seedlings may be dwarfish. It is probable that some of the seed used in these experiments which germinated following relatively short periods of after-ripening would have developed into dwarfish seedlings.

Field Observations:—The four lots of commercial Lovell seed which were sampled in the field on December 5 and germinated in the laboratory had been subjected to 76 days of after-ripening by that time. Although no records of soil temperature were secured, the conditions were favorable to optimum after-ripening, since the soil was lightly covered with snow and frozen to a depth of 2 inches. The four lots germinated as follows:

Lovell 1—20 per cent, compared with 40 per cent by germination test.
Lovell 2—100 per cent, compared with 100 per cent by germination test.
Lovell 3—0 per cent, compared with 14 per cent by germination test.
Lovell 4—100 per cent, compared with 100 per cent by germination test.

The results compare favorably with the laboratory results with the Lovell variety, in which maximum germination was not reached before 11 weeks of after-ripening.

Discussion

No attempt is made from this one season's work to say that the results reported are characteristic of the varieties used. The emphasis is placed on the fact that variations do exist in the after-ripening requirements of different lots of peach seed, at least in some seasons, leaving the question of varietal characteristics to further study.

The differences in the results with different varieties and lots of peach seed, both experimentally and from field observations, suggest that there are still factors in operation in the after-ripening and germination of peach seed which are not yet fully appreciated. Each variety and source of seed shows some degree of individuality insofar as after-ripening and germination are concerned.

Some of the contributing factors to this variability may be suggested. First of all, the season of ripening of the fruit bears a definite relation to the chemical composition of the embryo (8). The early-ripening varieties have abortive embryos with high moisture content and low content of ether extract and protein (5, 7, 8,). Seeds of later-ripening varieties have a low moisture content and high content of ether extract and protein. Second, the condition and composition may vary in different geographical regions. The embryo of the Early Purple Guigne cherry develops to larger size and has a higher fat content when grown in California than when grown at Geneva, N. Y. (4). Third, the chemical composition may vary from season to season in the same locality and may be affected by cultural conditions and by the cropping of the tree. Fourth, the conditions of handling and storage may affect the seed. After the seed is stored, it may dry out appreciably and the conditions which are provided may affect respiration and bring about chemical changes which, in turn, affect the period of after-ripening required for germination.

Conclusions

Each variety and source of seed has specific after-ripening requirements. Some lots show a high percentage of germination following a short period of after-ripening (2 to 3 weeks), while others do not reach maximum percentage germination until after-ripened for 11 to 12 weeks, or possibly longer. With most varieties there is a steady increase in percentage germination and in development of vigorous seedlings up to about the 10th week of after-ripening. For commercial procedure, 10 to 12 weeks of after-ripening at 3 to 5 degrees C is probably a good standard but with provision for either natural or artificial means of arresting germination in case it begins before this period has elapsed—as by fall planting or controlled low temperature storage.

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Morphological Changes in Peach Seedlings Induced by After-Ripening Treatments of the Seed

By H. B. Tukey and R. F. Carlson, *New York State Agricultural Experiment Station, Geneva, N. Y.*

Abstract

This paper will be published in full in the *Botanical Gazette* 106: 431–440. 1945.

More than 10,000 peach seed, involving 19 varieties and 17 sources, were after-ripened in moist peat moss at 34 to 36 degrees F for weekly intervals ranging from 1 to 12 weeks, and then germinated and grown to seedling size at 68 degrees F.

Some of the plants which developed were dwarfish, with anomalous leaves, resembling plants grown from excised-embryos of non-after-ripened seed. Leaves were sometimes short and broad rather than lanceolate, crinkled along the midrib, with uneven development of halves of the blade, and with whitish patches at the margins. Other leaves were small and stipule-like. A rosette of anomalous leaves frequently appeared at the apex of the epicotyledonary axis.

The dwarfish and anomalous plants in any given lot were most frequent among samplings which were after-ripened for the shortest period of time. As the after-ripening period lengthened, the dwarfish and anomalous plants became less frequent until finally after 12 weeks of after-ripening, no dwarfish or anomalous plants appeared.

The frequency of dwarfish and anomalous plants varied with the variety. Varieties which appear to have a relatively short after-ripening requirement produced no dwarfish or anomalous plants even with as little as 3 weeks of after-ripening. Varieties which appear to have an intermediate after-ripening requirement, produced both dwarfish and non-dwarfish plants through the 6-week period of after-ripening. Varieties which appear to have a relatively long after-ripening requirement produced dwarfish plants even after 11 weeks of after-ripening.

When some seeds in a given lot germinated and other seeds did not, the embryos of non-germinating seeds were excised and grown to seedling size. Many of the plants were dwarfish, with anomalous leaves, the frequency being higher from the excised than the non-excised lots receiving the same length of after-ripening.

Seeds of the Lovell and Elberta varieties were after-ripened for weekly intervals of 1 to 12 weeks. Some seeds were excised and some not, and seedlings were grown from both. The frequency of dwarfish and anomalous plants was greater with the Lovell than the Elberta variety for the same period of after-ripening, and the frequency of such plants was greater among the excised lots.

The dwarfish and anomalous forms are not the result of photoperiod alone, inasmuch as both "normal" and dwarfish seedlings developed from seed plants on the same day.

Twelve lots of Lovell and Kentucky Natural seed were planted

at successive weekly intervals from 1 to 12 weeks in an environment favorable to after-ripening, and then all removed and planted on the same day. Dwarfish and anomalous seedlings developed from seed which was after-ripened for relatively short periods (3 to 6 weeks), but no such seedlings developed from seed which was after-ripened for relatively long periods (10 to 12 weeks).

The dwarfish and anomalous growth of peach seedlings only rarely occurred in parts other than the epicotyledonary axis and its appendages. New shoots which were induced from axillary buds were free from abnormalities.

At least two steps are involved in the after-ripening and development of "normal" peach seedlings. First, there is the breaking of dormancy; second, and lagging behind, is the conditioning of the embryo so that the resulting seedling is free from dwarfish and anomalous plant characters.

Ripening of the Italian Prune as Related to Maturity and Storage

By Fisk Gerhardt and Harley English, *U. S. Department of Agriculture, Wenatchee, Wash.*

Studies in 1941 (3) showed that flesh color in conjunction with the solids-acids ratio might serve as a satisfactory index for the proper harvest of the Italian prune. The results also indicated that immediate storage at 31 degrees F impairs the normal ripening of this variety.

The present report contains further information on factors influencing the ripening of the Italian prune. The work was enlarged to include fruit grown under varying cultural conditions from three producing districts in the Pacific northwest. Special emphasis was given to the use of partial pre-storage ripening as a factor in the control of injury by low temperature.

Experimental Procedure

From 30 to 50 pounds of fruit were picked, usually at weekly intervals, from carefully selected trees in orchards located at Freewater, Oregon, Cashmere, Washington, and Stemilt Hill near Wenatchee, Washington. Well composited lots of fruit from each location and picking were used at harvest to evaluate certain indexes of maturity, while comparable samples were used for the storage and ripening observations.

Methods for the determination of the maturity indexes were similar to those described in the earlier report (3). Fruit from the Cashmere and Wenatchee orchards was stored immediately in 14-pound lugs at 31 and 42 degrees F, while comparable lots were delayed at 65 degrees F for 3 days prior to being placed at the above temperatures. Facilities were not available for placing the samples from the Oregon orchard in storage immediately after picking, therefore all lots from this orchard were delayed 3 days at 65 degrees F before storage at 31 and 42 degrees F. All samples remained in cold storage for 14 days before removal to 65 degrees F for ripening.

Results

Maturity Indexes:—Data relating to the appearance and composition of the various experimental lots of fruit at harvest are summarized in Table I. While firmness, total acids, and soluble solids can be of value in evaluating changes in maturity of the fruit from a single orchard, none of these can be used alone as a dependable index of maturity when the comparison is made between different orchards. For example, soluble solids in the fruit from the first picking from the Wenatchee orchard (when the fruit obviously was too immature for good dessert quality) were higher than those of the fourth picking from the Cashmere orchard. Similar inconsistencies were found between firmness and total acids.

Data in Table I show that color of the flesh together with the solids-acid ratio are the two most dependable indexes of maturity for

TABLE I—PHYSICAL AND CHEMICAL CHARACTERISTICS OF FRUITS OF THE ITALIAN PRUNE AS INFLUENCED BY MATURITY AT HARVEST, 1944

Date Harvested	Color: Skin	Color: Flesh	Firmness pressure test (Pounds)	pH	Total Acids (Per Cent)	Soluble Solids (Per Cent)	Solids: Acid Ratio	Weight 50 Fruits (Gms)	Increase in Weight (Per Cent)
Freewater, Oregon, Orchard									
Aug 20	Greenish to medium purple	Light green to light amber	10.9	3.19	1.36	14.7	10.8	1,690	0.0
Aug 27	Light to dark purple	Medium amber	9.6	3.41	1.09	16.0	14.7	1,785	5.62
Sep 1	Dark purple	Dark amber to light apricot	7.0	3.44	0.92	19.4	21.0	1,850	3.64
Cashmere, Washington, Orchard									
Aug 24	Mostly light purple	Light green to light amber	12.2	3.25	1.43	12.0	8.4	1,181	0.0
Aug 29	Light to medium purple	Light amber	11.2	3.38	1.25	13.3	10.6	1,261	6.77
Sep 5	Mostly medium purple	Medium amber	9.0	3.47	1.12	14.3	12.7	1,342	6.42
Sep 12	Dark purple	Dark amber	7.9	3.53	1.04	15.6	15.0	1,434	6.85
Stemilt Hill, Wenatchee, Washington, Orchard									
Sep 12	Mostly light purple	Light to medium amber	8.9	3.35	1.36	16.0	11.7	1,280	0.0
Sep 19	Medium purple	Dark amber	8.0	3.36	1.21	18.0	14.9	1,375	7.42
Sep 26	Dark purple	Light apricot	6.9	3.42	1.16	21.6	18.6	1,469	6.83

the Italian prune. This is especially true when comparisons are made between fruit from different orchards. Regardless of orchard location, fruit with a flesh color of light green to light amber and a solids-acid ratio of less than about 13 failed to attain satisfactory dessert quality. The acceptable maturity range for Italian prunes required a flesh color varying from medium to dark amber and a solids-acid ratio between 13 and 15. When flesh color was more intense (light apricot) and the solids-acid ratio was greater than 15 as in the last pickings from the Freewater and Wenatchee orchards, the fruit was usually too ripe for distant shipment.

Storage and Ripening Observations:—Results of ripening 34 lots of Italian prunes from three orchards following storage for 14 days are summarized in Table II. The main object in this study was to observe the course of ripening of the stored fruit as affected by maturity, handling, and storage temperatures.

The observations made in the previous report (3) that fruits of the Italian prune will not stand immediate storage at 31 degrees F without injury to the subsequent ripening capacity of the fruit, found confirmation in the data of Table II. This fact is important in the commercial handling of the fruit, since it means that a given lot of fruit may appear to be in good condition while in storage and still deteriorate quickly and seriously after removal to a higher temperature. As stated by Vincent, Verner, and Blodgett (5), too much confidence should not be placed in the appearance and condition of the fruit while it is in storage as more deterioration—decay, shriveling, and internal browning—may take place in 3 days after removal from storage than during the whole storage period. In the present study abnormal ripening could not be correlated with maturity of the

fruit at harvest or with differences in orchard location; it was, however, directly associated with the method of handling fruit prior to storage at 31 degrees F. Immediate storage at 31 degrees F delayed ripening and often resulted in injury to the flesh as shown in Fig. 1. Partial ripening for 3 days prior to storage at 31 degrees F eliminated all apparent injury from low temperature.

TABLE II—DESSERT QUALITY AND CHARACTER OF RIPENING OF ITALIAN PRUNES AS INFLUENCED BY MATURITY, HANDLING, AND STORAGE TEMPERATURE

Date of Harvest	Storage Treatment[1]		Time Required to Reach Best Quality (Days)	Observations on Ripened Fruit		Type of Ripening
	Temperature (Degrees F)	Prestorage Delay 65 Degrees F (Days)		Dessert Quality	Period to Over-ripeness or Breakdown (Days)	
Freewater, Oregon, Orchard						
Aug 20	42	3	5	Fair	7	Normal
	31	3	7	Fair	13	Normal
Aug 27	42	3	4	Very good	5	Normal
	31	3	6	Good	7	Normal
Sep 1	42	3	2	Excellent	3	Normal
	31	3	4	Excellent	6	Normal
Cashmere, Washington, Orchard						
Aug 24	42	0	7	Poor to fair	9	Normal
		3	6	Poor to fair	9	Normal
	31	0	9	Poor	9	Abnormal[2]
		3	8	Poor to fair	12	Normal
Aug 29	42	0	5	Fair	8	Normal
		3	5	Fair	8	Normal
	31	0	5	Poor	5	Abnormal
		3	8	Fair	10	Normal
Sep 5	42	0	3	Good	5	Normal
		3	2	Good	4	Normal
	31	0	5	Poor	5	Abnormal
		3	6	Good	8	Normal
Sep 12	42	0	2	Good	4	Normal
		3	2	Good	3	Normal
	31	0	4	Poor	5	Abnormal
		3	5	Good	7	Normal
Stemilt Hill, Wenatchee, Washington, Orchard						
Sep 12	42	0	4	Poor	6	Abnormal
		3	3	Poor	5	Normal
	31	0	7	Poor	9	Abnormal
		3	8	Poor	10	Normal
Sep 19	42	0	4	Good	6	Normal
		3	2	Very good	4	Normal
	31	0	6	Poor	8	Abnormal
		3	7	Very good	9	Normal
Sep 26	42	0	3	Good	4	Normal
		3	2	Good	3	Normal
	31	0	6	Poor	7	Abnormal
		3	5	Good	7	Normal

[1]All lots held in storage 14 days prior to ripening at 65 degrees F.
[2]The fruit when fully ripened was either mealy and dry or rubbery in texture. Under such conditions the fruit usually evidenced discoloration and breakdown of the flesh adjacent to the pit before reaching acceptable dessert quality.

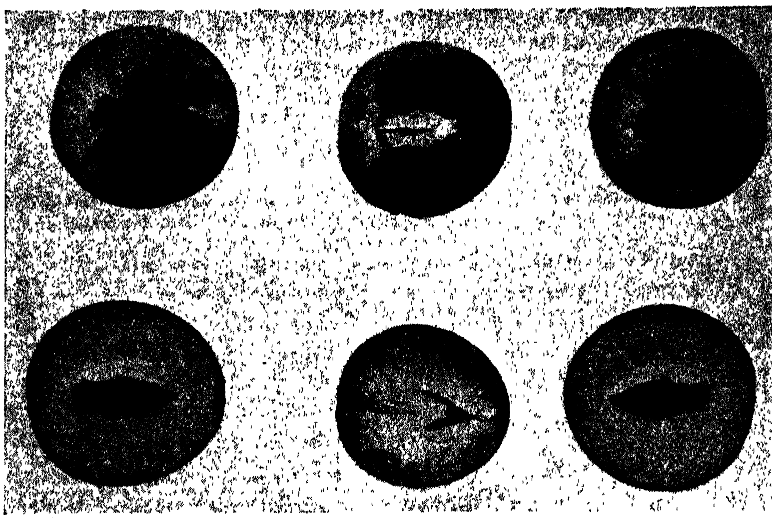

FIG. 1. Flesh discoloration and tissue breakdown in ripened Italian prunes. Top row: Low temperature injury found in fruit ripened at 65 degrees F for 5 days following storage at 31 degrees F for 14 days immediately after harvest. Bottom row: Comparable normal fruit ripened at 65 degrees F for 5 days, following delay of 3 days at 65 degrees F prior to regular storage at 31 degrees F for 14 days.

The possible range in acceptable storage requirements for fruits of the Italian prune is shown in Table II. Lots held at 42 degrees F for 14 days ripened normally with a dessert quality equally as good or better than that of comparable fruit held at 31 degrees F. After removal from storage those lots placed immediately at 42 degrees F still required several days to ripen to best dessert quality.

Under present commercial practice, the warm fruit is usually loaded directly into the refrigerator car and, at best, given not more than a few hours of pre-cooling. Average fruit temperatures in the load are rarely lowered to 50 degrees F prior to transit, and during transit are seldom lower than 42 degrees F. Probably for these reasons, the type of low temperature injury shown in Fig. 1 has not been reported from the terminal markets.

A type of low temperature injury known as "wooliness" (mealiness) has been reported in peaches grown in South Africa (1), (4). Fisher and co-workers (2) found that certain varieties of Canadian-grown peaches were also injured by prompt storage at 31 degrees F. In all these instances the injury was prevented by subjecting the fruit to a ripening period of several days at 65 to 75 degrees F prior to storage at 31 degrees F. Data in Table II and Fig. 1 indicate that the Italian prune also is injured by prompt storage at 31 degrees F, and that this injury may be prevented by the same pre-ripening practice that is used with peaches.

Summary

In this study, the variation in the maturity of Italian prunes from different orchards and grown under different cultural practice was great enough to preclude the use of firmness, or total acids or soluble solids as dependable single indexes of when to harvest the fruit.

In all the experimental lots studied, it was found that color of the flesh together with the solids-acid ratio was the most satisfactory guide to the proper time to harvest. Fruit with the flesh of a medium-to-dark amber color and a solids-acid ratio of 13 to 15 was judged to be acceptable for long-distance shipment.

Following immediate storage at 31 degrees F a low temperature injury developed in Italian prunes which was characterized by abnormal ripening (mealiness) of the fruit and discoloration and breakdown of the flesh. A serious amount of breakdown was usually observed at about the time the fruit had ripened to best dessert quality. In comparable fruit partially ripened prior to storage at 31 degrees F, breakdown appeared as a natural consequnce of over-ripeness but not until several days after it had reached best dessert quality. The storage disorder was prevented by partially ripening the fruit prior to storage at 31 degrees F or by holding it at temperatures of 40 degrees to 45 degrees F.

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Breaking the Dormancy of Peach Seed by Treatment with Thiourea

By H. B. Tukey and R. F. Carlson, *New York State Agricultural Experiment Station, Geneva, N. Y.*

Abstract

This paper will be published in full in *Plant Physiology*.

Thirty-four lots of peach seed, including 23 varieties, were treated with various concentrations of thiourea in aqueous solution.

The dormancy of Lovell peach seed was broken by treatment with thiourea. Of the 22 other varieties similarly treated, the dormancy of six was not broken, ten germinated 10 per cent, and all remaining varieties responded to a lesser degree than did the Lovell.

Lovell seedlings which developed from non-after-ripened seed whose dormancy was broken by treatment with thiourea were dwarfish, with shortened internodes and anomalous leaves, typical of seedlings from non-after-ripened, excised embryos.

Complete after-ripening of peach seed accomplishes more than a conditioning of the seed to germinate; it involves, also, changes in the seed which result in vigorous seedlings free from dwarfish and anomalous characters.

The most favorable treatments to break the dormancy of non-after-ripened Lovell seed were soaking for 2 to 16 hours in .25 to .5 per cent solution of thiourea or placing in a continuous supply of .25 per cent solution.

Lovell seed which was treated with thiourea while still enclosed in the stony pericarp failed to germinate, but germinated when removed from the stony pericarp.

Seed coats of after-ripened Lovell seed were checkered in appearance and the cotyledons became enlarged during germination, whereas non-after-ripened, thiourea-treated Lovell seed did not have this appearance and did not enlarge in this way.

Molds and common seed-borne fungi were reduced by treatment of seed with thiourea.

Observations on Growth Differences of Sweet and Sour Cherries Grafted onto Mazzard and Mahaleb Body Stocks[1]

By K. D. Brase, *New York State Agricultural Experiment Station, Geneva, N. Y.*

In an earlier publication (1) it was reported that the sweet, as well as the sour cherry, can, during the dormant season, be bench-grafted to oversized Mazzard and Mahaleb seedlings. The purpose of this paper is to present observations on the growth behavior in the young orchard of a few trees propagated by this method, for preliminary trial.

Materials and Methods

In early May, 1940, five and four trees respectively of the sweet cherry, variety Giant, and of the sour cherry, variety Montmorency, which had been grafted onto seedlings of Mazzard (*Prunus avium* L.) and Mahaleb (*P. Mahaleb* L.), were planted in the young orchard at Geneva in a row 15 feet apart. The trees had been bench-grafted to the seedlings of Mazzard and Mahaleb at a height of 26 inches, measured from the crown, and as grafts had been growing for two seasons in the nursery row. Care was taken in the selection of trees in regard to uniformity of root system and diameter of the body stock. The planting was repeated in 1943 with trees propagated and selected the same way.

The soil at the location is a gravelly loam, well drained and well suited for cherries. All trees were grown in sod, the grass being cut at least twice during the summer and left as mulch. A light application of ammonium sulphate was given each spring, beginning with the second year after planting.

Observations

Growth:—The trees in both plantings transplanted well and made satisfactory growth at their new location. Differences in top growth were very slight or non-existant after the first growing season, but differences in increase of trunk diameter were quite distinct. The Mazzard trunk in each case made a more rapid increase than the Mahaleb trunk; trees with a Montmorency top made a slightly more rapid trunk diameter increase on Mazzard and Mahaleb than did those having the sweet cherry, variety Giant, as top. The greater increase of trunk diameter of Mazzard had a noticeable effect on top growth of both varieties during the third growing season. Tops on Mahaleb now appeared smaller than those on Mazzard. This was particularly the case with the variety Giant, but also the top of Montmorency on Mahaleb was decidedly smaller. At the end of five growing seasons the average total growth, measured in trunk diameter,

[1]Journal Paper no. 625 of the New York State Agricultural Experiment Station.

was: Giant on Mazzard 85.8 mm^2 as compared with Giant on Mahaleb 38.8 mm, a difference of 47 mm; Montmorency on Mazzard measured 91.8 mm and on Mahaleb 50.5 mm, a difference of 41.3 mm (Table II). Thus, Montmorency made the greater gain on both body stocks than did Giant, but in each case trees on the Mahaleb trunk were decidedly dwarfed (Figs. 1 and 2).

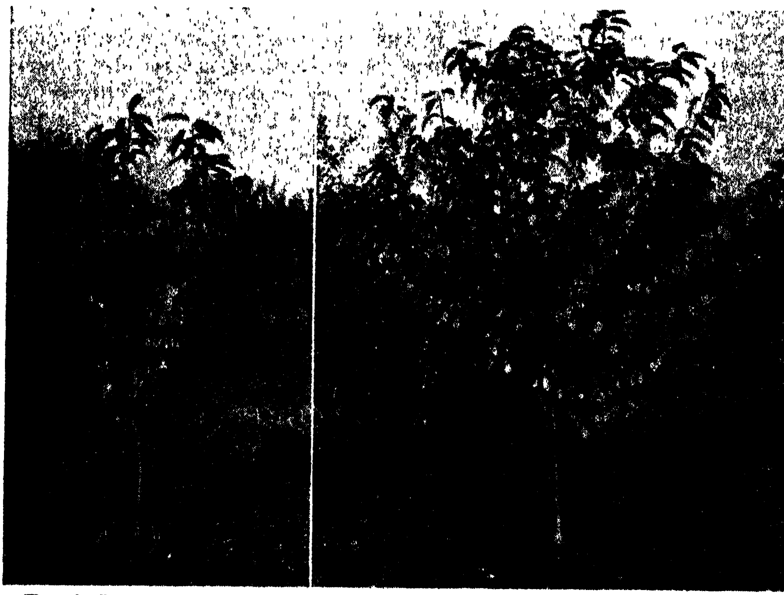

FIG. 1. The sweet cherry variety Giant after five seasons of growth in the orchard row, bench-grafted at 26 inches above the root. (A) Mahaleb; (B) Mazzard.

Trees planted in 1943 behaved in much the same way. There were only very slight or no differences observable in top growth during the summers of 1943 and 1944, but, again, differences in trunk diameter increase were outstanding. The measurements taken at the end of the 1944 growing season were Giant on Mazzard 35 mm and on Mahaleb 27.5 mm, whereas Montmorency, again, on both Mazzard and Mahaleb made somewhat more rapid trunk diameter increase. With Montmorency, the trunk diameter measured 41.8 mm on Mazzard and 34 mm on Mahaleb (Table I).

Fruiting:—All trees planted in 1940 on Mahaleb body stocks, both the Giant and Montmorency varieties, bore a few fruits the third season from planting and showed slight increases in fruiting the fourth and fifth seasons. Giant on Mazzard bore a few fruits during 1944, but no fruit has been borne so far by Montmorency on Mazzard (1944). None of the trees planted in 1943 have borne fruit up to 1944.

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[2]All trunk diameter measurements were taken at a place midway between union and ground level.

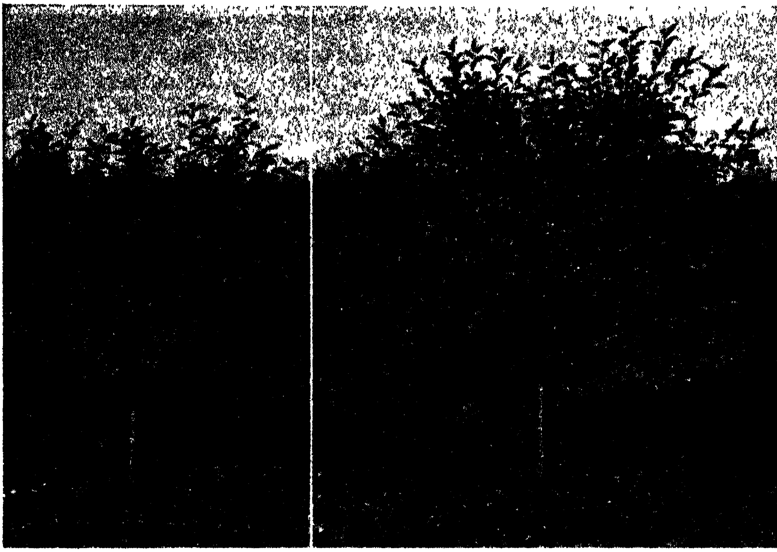

FIG. 2. The sour cherry variety Montmorency after five seasons of growth in the orchard row, bench-grafted at 26 inches from the root. (A) Mahaleb; (B) Mazzard.

TABLE I—DIFFERENCES IN TRUNK DIAMETERS OF CHERRY TREES TOP-WORKED ON MAZZARD AND MAHALEB SEEDLINGS. PLANTED 1943, TWO SEASONS OF GROWTH

Variety and Body Stock	Trunk Diameter of Individual Trees at Planting (mm)						Mean	Trunk Diameter of Individual Trees After Five Seasons (mm)						Mean
Giant/Mazzard . . .	20	20	19	19	19	—	19 4	43	35	30	30	37	—	35.0
Giant/Mahaleb .	14	14	16	16	15	15	15.0	27	25	28	31	29	25	27.5
Montmorency/Mazzard .	21	19	20	19	18	20	19.5	45	40	53	38	35	40	41.8
Montmorency/Mahaleb .	17	16	16	15	15	16	15.8	43	32	38	30	31	30	34.0

Difference between Means:
- Giant at time of planting . . . . 4.4 mm
- Giant after two seasons of growth . . . . 7.5 mm
- Montmorency at time of planting . . . . 3.7 mm
- Montmorency after two seasons of growth . . . . 7.8 mm

TABLE II—DIFFERENCES IN TRUNK DIAMETERS OF CHERRY TREES TOP-WORKED ON MAZZARD AND MAHALEB SEEDLINGS. PLANTED 1940, FIVE SEASONS OF GROWTH

Variety and Body Stock	Trunk Diameter of Individual Trees at Planting (mm)						Mean	Trunk Diameter of Individual Trees After Five Seasons (mm)						Mean
Giant/Mazzard..........	18	18	18	17	17	—	17.6	101	94	84	73	77	—	85.8
Giant/Mahaleb..........	15	15	14	14	—	—	14.5	52	42	27	34	—	—	38.8
Montmorency/Mazzard ..	20	20	19	18	18	—	19.0	104	95	90	85	85	—	91.8
Montmorency/Mahaleb ..	17	16	17	16	—	—	16.5	63	51	50	38	—	—	50.5

Difference between Means:
- Giant at time of planting . . . . 3.1 mm
- Giant after five seasons of growth . . . . 47.0 mm
- Montmorency at time of planting . . . . 2.5 mm
- Montmorency after five seasons of growth . . . . 41.3 mm

Discussion

Although the Mahaleb rootstock is considered somewhat growth-restricting, cherry trees grown for two years in the nursery on this stock are vigorous and are larger than such trees on the Mazzard stock (4), but in commercial nursery practice cherry trees are budded to the rootstock just above the soil surface; thus, a very short stem portion of the rootstock is involved in producing the tree. With such trees, when grown on a soil suitable for cherry culture, growth-restricting influences of the Mahaleb root do not occur (4) or they appear only some years after planting (2). Grubb (3), growing the variety English Morello on Mazzard and Mahaleb roots, showed by shoot and trunk measurements the greater vigor of trees on Mahaleb in their early years. His findings confirm those of Howe (2) and Upshall (4).

As shown in Tables I and II and by Figs. 1 and 2, a distinct dwarfing of cherry trees is obtained by using the Mahaleb understock as both root system and body stock, and using the desired variety to form the top. The varieties Giant and Montmorency, beforementioned, appear entirely congenial with the Mahaleb body stock and have made a faultless union. Although it is most desirable to carry on further observations on the growth behavior of such trees, their performance so far has been entirely satisfactory.

The nursery industry is asking the question "Is there a possibility of having sweet or sour cherry varieties as trees which in size will compare with the dwarf apple tree as such on Malling IX?" Cherry trees propagated in the conventional way will not fill this need. Tests and observations above reported show that by using a Mahaleb root system and body stock, a satisfactory union can be obtained when a sweet or sour cherry variety is grafted to the body stock. The Mahaleb trunk will further restrict the growth of the top to such an extent that the resulting tree will be much dwarfed and in size compare with that of dwarf apple trees.

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Some Factors Influencing the Growth of Date Offshoots in the Nursery Row

By W. W. ALDRICH, G. H. LEACH, and WILLIAM A. DOLLINS, *U. S. Department of Agriculture, Washington, D. C.*

THE time of year to cut date offshoots from the parent palms and the current methods of caring for newly planted offshoots have been based largely upon reports of customs in the old date-growing regions of Asia and Africa and upon experience of observant growers in the United States. However, the frequent occurrence of high mortality or very poor growth of newly planted offshoots in this country has emphasized the need of investigation of factors influencing offshoot development. To supplement the experimental results obtained about 20 years ago by Crider (3), such factors as time of cutting and planting, size of offshoot, wrapping, and frequency of irrigation were studied at the U. S. Date Garden, Indio, Calif., from 1938 to 1943.

FIG. 1. Date palm offshoot without roots, weighing about 60 pounds, trimmed and ready to plant. Note that the lowest leaves have been cut off, leaving the spiny leafstalks of a few fully expanded leaves surrounding the young expanding leaves. Leaf growth, as measured subsequent to planting, was the maximum extension of a new leaf above the cut end of the highest spiny leafstalk.

METHODS

All offshoots were cut, trimmed as shown in Figure 1, planted, and irrigated within 24 hours. Offshoots weighing between 20 and 34 pounds were termed "small," between 38 and 52 pounds "medium," and between 60 and 82 pounds "large." Unless otherwise specified here, burlap was wrapped around the spiny leafstalks at the time of planting. Leaf extension

subsequent to planting was measured as the distance from the cut end of the highest spiny leafstalk (elongation of this had ceased) up to the tip of the terminal pinnae on the leaf making the greatest elongation.

Preliminary Experiments

In June, 1938, offshoots were cut from Zahidi palms which had always suffered from insufficient soil moisture and which, because of low temperatures in January, 1937, had a relatively small number of leaves per palm during the 17 months preceding offshoot removal. Some of these offshoots were high on the trunk, others at the soil surface. Very few showed any root development. The offshoots were sorted for size and root development and planted in a fine sandy loam. One lot of each type was irrigated at different frequencies. As a result of high sodium saturation of the colloids in this soil, infiltration of irrigation water was so slow that, following a 4-acre-inch irrigation, some water usually remained in the irrigation basins for three or four days.

During July and August, 1938, all offshoots showed some leaf growth, but during the next 18 months offshoot mortality was high and leaf extension very slow, as indicated in Table I. Offshoots that

TABLE I—Effect of Original Root Development, Size of Offshoots and Interval Between Irrigations Upon Leaf Extension and Mortality of Zahidi Offshoots Planted on June 30, 1938, in a Fine Sandy Loam Soil Relatively Impervious to Water

Interval Between Irrigations (Days)	Root Condition When Planted	Number of Offshoots Planted	Leaf Extension of the Surviving Offshoots of Each Size by Feb 9, 1940			Percentage of Offshoots of Each Size Dead by Feb 9, 1940		
			Small (Cm)	Medium (Cm)	Large (Cm)	Small	Medium	Large
14	No roots	8	38	33	16	13	38	50
	Roots	5	72	93	87	0	0	0
7	No roots	16	24	18	42	69	57	88
	Roots	8	66	64	58	13	13	25
3 or 4	No roots	8	9	20	52	50	75	88

showed root development when cut and planted had a much lower mortality and made slightly more leaf extension than comparable offshoots without roots. For offshoots without roots at planting as well as for those with roots, the 14-day interval between irrigations resulted in less mortality and, in general, in greater leaf extension than did the 7- or the 3-to-4-day intervals for offshoots of corresponding sizes. Inasmuch as some irrigation water was standing on the surface all the time with 3-to-4-day intervals between irrigations and about half the time with 7-day intervals, the generally poor offshoot development with the shorter intervals was probably the result of surface water so reducing air movement into the warm soil that the roots did not have enough oxygen for normal development and for water and nutrient intake. Very low soil-oxygen values under stand-

ing water were later found in this soil by Furr and Aldrich (4). The small and medium offshoots survived as well as, if not better than, the large ones.

Large Maktoom offshoots with roots, planted at the same time, showed about 50 per cent mortality with the 3-to-4-day interval between irrigations, and only about 25 per cent mortality with the 7- and the 14-day interval.

To study effect of time of planting of offshoots in this same soil, eight offshoots of Hayany and Saidy, respectively, were cut and planted on each of the following dates: December 1, 1938; February 1, 1939; April 1, 1939; and June 1, 1939. All offshoots had roots when planted. Irrigations were at least 1 week apart. The time of planting did not have any marked effect upon leaf extension or upon mortality of the offshoots.

Number of Offshoots on Parent Palm

To determine the effect of the number of offshoots on a parent palm upon growth of the offshoots when cut and planted, ten pairs of young Halawy palms with 10 to 15 offshoots each were selected, the palms in each pair being very similar in size and number of offshoots. The two largest offshoots on each palm were tagged for subsequent study. In October, 1938, all but the two tagged offshoots were cut off one palm in each pair, all offshoots being left on the other palm. During the summer of 1939 soil moisture deficiencies probably occurred just prior to each irrigation. Eighteen months later these tagged offshoots were cut, weighed and planted. The initial growth of these offshoots and the performance of the parent palms are reported in Table II.

TABLE II—Effect of Removing All But Two Offshoots of Halawy Palms Upon Weight and Growth of the Tagged Offshoots and Upon Growth and Flowering of Parent Palm

Halawy Palms	All Offshoots Left on During October, 1938, to Apr. 1940	All Offshoots But Two Cut Off in Oct, 1938
Average weight per tagged offshoot cut on April 5, 1940 (lbs)	59	73*
Leaf extension of offshoots during first three months after planting (cm)	19	29*
Increase in height of fiber line during period from July 6, 1939, to April 8, 1941, average per parent palm (cm)	76	89*
Number of inflorescences per parent palm		
Spring 1940	7	7
Spring, 1941	10	13*
Spring, 1942	11	12

*Value greater than for palms with all offshoots left on, by odds of 99:1.

When only two offshoots were left on the parent palm during the 18 months prior to offshoot cutting and planting, these offshoots averaged 24 per cent heavier and made 53 per cent greater growth extension during the first 3 months after planting than did comparable offshoots from parent palms with all offshoots left on. Since the parent palms with only two offshoots made 17 per cent greater trunk growth than did the parent palms with 10 to 15 offshoots, the offshoots had

an appreciable effect on the parent palms perhaps by competing with the parent-palm top for water or mineral nutrients coming through the parent-palm roots or for carbohydrates from the parent-palm leaves. Therefore, with only two offshoots per palm, it is possible that either the carbohydrate synthesis by the parent palm was greater or the translocation of carbohydrates and perhaps of other growth substances to each offshoot was greater, than with 10 to 15 offshoots per palm.

It is interesting that reducing the number of offshoots per parent palm in October, 1938, did not affect the number of influorescences in 1940, but did increase the number in 1941. Apparently conditions affecting differentiation or emergence of influorescences appearing in 1941 occurred between 12 and 36 months before the influorescences appeared.

Irrigation, Size of Offshoot, and Delay in Planting

From parent palms of the Deglet Noor variety which produced their first crop in 1940, 48 offshoots each of the small, medium and large sizes, respectively, were planted in 1941 to determine the effects of interval between irrigations for a fine sand very pervious to water. The offshoots had been in contact with the soil and all had started root development. One offshoot of each size was planted in each of the 48 plots, which received one of the three methods of offshoot handling in each of the four irrigation treatments that were replicated four times. Thus, there were four offshoots of each size in each frequency of irrigation. At each irrigation the soil surface to a distance of at least 3 feet from the offshoot was flooded with 4 to 5 inches of water. The specific intervals between irrigations were maintained only during the first 7 months after planting. The treatments and results are given in Table III. These Deglet Noor offshoots showed an unexpectedly high mortality that could not be correlated with size or vigor of the parent palms or with any environmental or cultural factor other than small size of the offshoot. As a result of this high mortality, there are too many missing values of leaf extension to permit an accurate statistical analysis of the data in the experiment as a whole. In the case of the medium-sized offshoots with only six dead, the expected values for leaf extension for each of the missing offshoots were calculated and the data then subjected to analysis of variance.

The lack of any clear-cut relation of irrigation frequency to leaf extension or to offshoot mortality indicates that the interval between irrigations had very little influence upon offshoot development in this experiment. In the case of the medium offshoots, the greater shoot extension with the 2- or 3-day interval, as compared with the 7-day interval, was significant by odds of 19: 1, and as compared with the 10-day interval by odds of 99: 1.

Wrapping offshoots with burlap, as compared with no wrapping, did not have any consistent effect on leaf extension or on mortality. Although the delay in planting did not appear to increase offshoot mortality, it did generally result in less leaf extension than in offshoots planted immediately. In the case of the medium-sized offshoots,

TABLE III—EFFECT OF SIZE OF OFFSHOOT, WRAPPING WITH BURLAP, DELAY IN PLANTING, AND INTERVAL BETWEEN IRRIGATIONS UPON LEAF EXTENSION AND MORTALITY OF DEGLET NOOR OFFSHOOTS PLANTED IN APRIL, 1941, IN FINE SAND VERY PERVIOUS TO WATER

Interval Between Irrigations (Days)	Promptness in Planting	Wrapping with Burlap	Leaf Extension of Surviving Offshoots of Each Size by Aug 10, 1942				Percentage of Offshoots of Each Size Dead by Aug 10, 1942			
			Small (Cm)	Medium (Cm)	Large (Cm)	Average (Cm)	Small (Per Cent)	Medium (Per Cent)	Large (Per Cent)	Average (Per Cent)
2 or 3	Immediate	Wrapped	57	143	167	122	25	0	25	17
	Immediate	Not wrapped	100	140	123	121 } 117	25	25	25	25 } 22
	5-day delay	Wrapped	55	127	138	107	50	25	0	25
3 or 4	Immediate	Wrapped	90	125	77	97	25	50	25	33
	Immediate	Not wrapped	100	175	65	113 } 98	75	50	50	58 } 44
	5-day delay	Wrapped	—	75	93	84	100	0	25	42
7	Immediate	Wrapped	108	118	140	122	0	0	0	0
	Immediate	Not wrapped	105	103	73	94 } 100	50	0	25	25 } 17
	5-day delay	Wrapped	50	113	90	84	75	0	0	25
10	Immediate	Wrapped	—	108	98	103	100	0	0	33
	Immediate	Not wrapped	45	118	87	83 } 79	50	0	25	25 } 22
	5-day delay	Wrapped	65	33	57	52	0	0	25	8
Average of all irrigation frequencies	Immediate	Wrapped	85	124	121	—	38	12	12	—
	Immediate	Not wrapped	88	134	87	—	50	19	31	—
	5-day delay	Wrapped	57	87	95	—	56	6	12	—
Averages			81	115	101	—	48	12	19	

22 per cent less leaf extension with delayed planting was statistically significant by odds of 99: 1. Small offshoots showed much greater mortality than medium or large offshoots and made considerably less leaf extension.

Wrapping and Time of Planting

To determine the influences of wrapping and of time of planting, Khadrawy offshoots with roots were cut from young vigorous palms and planted at each of four different times in 1942. At each time of planting, 21 pairs of offshoots were set at different locations throughout three nursery rows. One offshoot of each pair was not wrapped and the other was wrapped with burlap. Final records, given in Table IV, were examined for statistical significance by analysis of variance.

TABLE IV—Effects of Wrapping with Burlap and of Time of Planting Upon Leaf Extension, Number of Leaves Produced, and Mortality of Khadrawy Offshoots During 2 Years in the Nursery

Time of Planting in 1941	Percentage of Offshoots Dead Dec 8, 1943		Leaf Extension by Dec 8, 1943		Total Number of Leaves Per Offshoot by Dec 8, 1943		Range of Soil Temperatures at 12 Inches Depth During First Month After Planting (Degrees F)
	Wrapped	Not Wrapped	Wrapped (Cm)	Not Wrapped (Cm)	Wrapped	Not Wrapped	
Feb 2	4.8	28.6	172	214	9.4	9.8	54-56
Apr 7	0	0	190	261	10.9	12.3	63-64
June 5	0	0	211	258	11.9	12.9	77-81
Jul 29	4.8	0	177	226	9.3	10.6	79-86
Differences required for odds 99:1			42		2.0		
Differences required for odds 19:1			32		1.5		

The growth of these offshoots was, in general, very good, but was influenced somewhat by the wrapping and the time of planting. No wrapping, as compared with wrapping, resulted in more leaf extension (odds 99: 1), but did not result in significantly more leaves per offshoot (over-all odds less than 19: 1). However, the lack of wrapping on offshoots planted in February was followed by the only considerable mortality of offshoots in this experiment. Planting in June resulted in more leaf extension and in more leaves for both wrapped and unwrapped offshoots than planting in February or in July. Without wrapping, the offshoots planted in April made about as good growth as those planted in June. In the case of the February 2 planting, soil temperatures in February and March may not have been sufficiently high for maximum root development. The magnitude of the difference in total leaf extension between the offshoots planted on June 5 and those on July 29 was no greater than the amount of leaf extension that had been made by the June 5 planted offshoots by the time of the cutting and planting of offshoots on July 29.

Summary

The very much higher mortality of nonrooted than of rooted (Zahidi) offshoots is in agreement with the results of Crider (3) and with commercial experience in the United States.

With rooted offshoots the experimental conditions that resulted in increased offshoot survival were (a) the use of medium or large, rather than of small Deglet Noor offshoots, (b) avoidance of sufficiently frequent irrigation of relatively water-impervious soil to cause water to stand on the surface either half or nearly all of the time, and (c) planting unwrapped Khadrawy offshoots in April, June, or July instead of in February.

Leaf extension of rooted offshoots was favored by these three experimental conditions and also by (a) immediate planting, as compared with a 5-day delay; (b) planting in June or (in the case of unwrapped offshoots) in April rather than in February; (c) reducing to two the number of offshoots per palm, instead of allowing 10 to 15 to remain on the parent palm during 18 months prior to cutting and planting; (d) a 2- or 3-day interval between irrigations of a pervious fine sand, as compared with a 10-day interval; and (e) no wrapping of vigorous Khadrawy offshoots as compared with wrapping with burlap.

These results substantiate many of the recommendations of Albert and Hilgeman (1), but raise some doubt as to the practices of wrapping offshoots or of cutting offshoots, at least of the Deglet Noor variety, until they have attained a weight of over 30 pounds.

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A Study of Rootstocks for Concord, Ontario, and Delaware Grapes

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In a recent paper, Loomis (2) has enumerated the objectives in the use of rootstocks for grapes and has summarized the work and the results obtained in rootstock research in the Southern states. The present paper records the findings from a rootstock experiment carried on at the Plant Industry Station, Beltsville, Maryland. This test was initiated in 1933 and concluded in 1942, using the following stocks: Rupestris St. George; Constantia; Solonis x Othello, No. 1613; Mourvedre x *Vitis rupestris,* No. 1202; *V. monticola* x *riparia,* No. 18815; Dog Ridge; *V. riparia* x *rupestris,* No. 3309; *V. riparia* x *rupestris,* No. 101–14; *V. cordifolia* x *riparia,* No. 125–1; *V. berlandieri* x *riparia,* No. 420–A; and Salt Creek. The scion varieties used were: Concord, Ontario, and Delaware.

The stock plants were set in the vineyard in March, 1933, and bud-grafted in the fall of the same year, using the method described by Snyder and Harmon (6). Those plants not showing positive scion growth the following spring were again grafted. A complete stand of grafted plants was not obtained and cleft-grafting was resorted to, with only partial success. The failure to obtain uniformly good grafts in all cases is reflected in the number of plants entering into the final records and accounts for most discrepancies.

The arrangement of the test plot was as follows: An outer row of stock vines serving as a buffer was followed by a row of own-rooted vines, and this by a row of grafted vines of a single stock top-worked to the three scion varieties. In like manner, rows of own-rooted and grafted vines alternated throughout the plot, with a final buffer row of stock plants completing the planting. Each stock test row was flanked on each side by own-rooted vines of the corresponding scion varieties. The rows were spaced at 10 feet and the vines were set 8 feet apart in the rows. Each row consisted of 38 plants arranged in the following order: 7 plants of Concord, 6 of Ontario, 6 of Delaware, 6 of Concord, 6 of Ontario, and 7 of Delaware; the two outer plants at the ends of the row served as buffers and were not considered in the final records. This arrangement provided for duplicate readings on two 6-vine groups of each stock-scion combination, except in the case of *Vitis cordifolia* x *riparia,* No. 125–1; *V. riparia* x *rupestris,* No. 101–14; *V. berlandieri* x *riparia,* No. 420–A; and Salt Creek, which, because of insufficient plants for a full-scale planting, were reduced to a half-row each, or 6 vines of each stock-scion combination instead of 12 as with the others. Stock vines acting as buffers in most cases filled the spaces where grafting attempts failed.

The test vineyard occupied a gravelly hill-slope having a north-western exposure. Half of the test vines in each unit received in the spring, annually, an application of 1 pound of nitrate of soda per vine, and the other half an application of ¾ pound per vine of 5–8–5 com-

plete fertilizer. Otherwise the cultural treatment was the same for all stock-scion combinations and the results are comparable. The vineyard fruit yields of stock-scion and adjacent own-rooted vines are given in Table I for the 5-year period 1938 to 1942, inclusive, only

TABLE I—FRUIT YIELDS OF CONCORD, ONTARIO AND DELAWARE GRAPES ON ROOTSTOCKS AND ON THEIR OWN ROOTS

Rootstock	Average Fruit Yield per Vine for 5-Year Period for Each Variety Receiving Sodium Nitrate (A), or 5-8-5 Fertilizer (B)					
	Concord		Ontario		Delaware	
	A (Ounces)	B (Ounces)	A (Ounces)	B (Ounces)	A (Ounces)	B (Ounces)
Rupestris St. George	145*	105	25	38	173	123
Own roots	98	116	96**	74**	187	140
Constantia	260**	216**	87	120*	305**	318**
Own roots	127	139	101	82	212	167
Solonis × Othello, 1613	119	166	82	56	227	213
Own roots	153	143	84	76	151†	180†
Mourvedre × *V. rupestris*, 1202	198	189	66	91	155	163
Own roots	143	143	70	96	132	163
V. monticola × *riparia*, 18815	182	227**	112	152*	257	284*
Own roots	139	159	96	115	223	178
Dog Ridge	198	161	45	67	165	212
Own roots	157	175	146**	119*	237*	205
V. riparia × *rupestris*, 3309	249*	318**	222	183	283*	203
Own roots	171	168	150	115	215	197
V. riparia × *rupestris*, 101 14	249*§	212	43§	136‡	237§	52‡
Own roots	149	130	116*	131	184	209*
V. cordifolia × *riparia*, 125-1	209§	466**‡	—	144§	226‡	267
Own roots	150	142	137	103	221	216
V. berlandieri × *riparia*, 420-A	305*‡	193§	116§	46	233	265§
Own roots	172	160	145	107	229	208
Salt Creek	196‡	117‡	26§	31‡	193*§	—
Own roots	152	141	131**	130	181	203

*Odds significant.
**Odds very significant.
†Abnormal conditions of vines in one row resulted in low yields and high variability.
‡One vine only.
§Two vines only.

the fully mature and therefore comparable vines entering into the consideration. The significance of differences in yields of stock-scion versus own-rooted vines was determined by the method of Fisher for unpaired small samples, as given by Love (3). From the weights of the prunings (Table II), the average annual wood production of each stock-scion combination, compared with the average annual production of the corresponding flanking own-rooted vines, was calculated and used as an index of vegetative vigor, but the data are not presented. Forty-two per cent of the fresh weight of the fruit and 54.6 per cent of the fresh weight of wood were used as factors in determining the total dry matter, these percentages being based on laboratory determinations of the moisture content of fruit and wood.

TABLE II—WEIGHT OF PRUNINGS OF VINES OF CONCORD, ONTARIO, AND DELAWARE GRAPES ON CERTAIN ROOTSTOCKS AND ON THEIR OWN ROOTS

Rootstock	Average Weight of Wood per Vine for 5-Year Period for Each Variety Receiving Sodium Nitrate (A), or 5-8-5 Fertilizer (B)					
	Concord		Ontario		Delaware	
	A	B	A	B	A	B
Rupestris St. George	53	26	25	21	55	30
Own roots	55	57**	26	26	47	33
Constantia	68	52	44**	38**	78**	67**
Own roots	57	60	25	25	50	36
Solonis × Othello 1613	40	60*	36	24	70	56
Own roots	51	40	22	20	31†	38†
Mourvedre × *V. rupestris*, 1202	80*	49	57**	55**	74	60
Own roots	51	41	19	23	33	37
V. monticola × *riparia*, 18815	51	35	40	37	71	58
Own roots	71	59	30	34	60	48
Dog Ridge	125**	62	68**	59	135**	83
Own roots	78	73	41	38	61	62
V. riparia × *rupestris*, 3309	60	82	61*	37	74	60
Own roots	69	72	39	36	68	64
V. riparia × *rupestris*, 101-14	79§	48	64*§	66*‡	64§	33‡
Own roots	71	55	38	36	76	74
V. cordifolia × *riparia*, 125-1	74§	107‡	—	44§	62‡	58
Own roots	88	75	38	37	64	60
V. berlandieri × *riparia*, 420-A	74‡	50§	42§	25§	47	76§
Own roots	83	70	37	36	73	61
Salt Creek	59‡	28‡	51§	33‡	63§	—
Own roots	68	61	40	37	73	61

*Odds significant.
**Odds very significant.
†Abnormal conditions of vines in one row resulted in low yields and high variability.
‡One vine only.
§Two vines only.

DISCUSSION

The yields of Concord and Delaware on Constantia stock were greater by very significant odds than where these varieties were on their own roots. Vine growth was equal in case of Concord, and greater in Delaware, when on Constantia stock. Shepard (5) found Constantia best of several rootstocks for these two varieties. Although Ontario on Constantia was much more vigorous than on its own roots, as shown by weight of prunings, the fruit yields on Constantia were greater than on its own roots only in the 5–8–5 fertilizer treatment.

The yields for all three varieties were higher on *Vitis monticola* x *riparia*, No. 18815, rootstock than on their own roots, but the differences were significant only on the plots receiving the 5–8–5 fertilizer. Wood growth was greater on Ontario and Delaware on the stock than on the own rooted vines but the differences were not statistically significant. When *V. riparia* x *rupestris* No. 3309, was the stock, yields were higher than own-rooted vines in all plots but the increase was significant only with Concord and for the Delaware plot receiving sodium nitrate. Vine growth was substantially the same on the stock

and on own-rooted vines. In Missouri, Shepard (5) found that *V. riparia* x *rupestris,* No. 3309, did not give as high yields of Concord and Delaware as did Constantia, but was best with the varieties Winchell and Eclipse.

Rupestris St. George, which Gladwin (1) found very satisfactory for Iona in New York and which Vaile (7) found to cause greater productiveness of Campbell in Arkansas than own-rooted vines, in the present tests resulted in reduced yield of Ontario below that of own-rooted vines, and only in the case of Concord vines receiving sodium nitrate did it seem to increase yield.

On Solonis x Othello, No. 1613; Mourvedre x *Vitis Rupestris,* No. 1202, and Dog Ridge as rootstocks, none of the three varieties had any greater fruit production than on their own roots. On Dog Ridge the grafted vines were in most cases more vigorous and the yield and quality of fruit was in most plots poorer than for comparable own-rooted vines.

The data on *Vitis riparia* x *rupestris*, No. 101–14; on *V. cordifolia* x *riparia*, No. 125–1; on *V. berlandieri* x *riparia,* No. 420–A; and on Salt Creek are too meager to warrant definite conclusions. The available evidence, however, does not show any particular value of these rootstocks for Concord, Delaware, and Ontario. In the single instance where a highly significant increase in fruit production for Concord on *V. cordifolia* x *riparia*, No. 125–1 (with 5–8–5 fertilizer) was shown, the results are based on a comparison of own-rooted vines with only a single vine on that rootstock.

The results with the Ontario variety show only two cases of greater yield with rootstocks than with own-rooted vines. Ontario on Rupestris St. George and on Dog Ridge produced less fruit than on its own roots. The meager evidence for Ontario on Salt Creek suggests that this rootstock also reduced the productivity below that of own-rooted vines.

Summary

Of the 11 grape rootstocks tested with Concord, Delaware, and Ontario scion varieties the rootstocks Constantia; *Vitis monticola* x *riparia*, No. 18815; and *V. riparia* x *rupestris*, No. 3309 were generally superior to own-rooted vines for Concord and Delaware. Increase in yield and vine growth was general on these varieties and stocks, though the increase in individual plots was not always significant. The yields of Concord and Delaware on the other rootstocks were greater than for own-rooted vines only in occasional combinations. The Ontario yields were less on most of the rootstocks than on own-rooted vines. Only on *V. monticola* x *riparia,* No. 18815, and on *V. riparia* x *rupestris,* No. 3309, were yields greater than on own-rooted vines, and these increases were not statistically significant.

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The Effect of Malling I, II and XIII Rootstocks on Several Apple Varieties[1]

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At the University Experiment Farm, Kearneysville, West Virginia, there are two small plantings of seven varieties of apples worked on three Malling rootstocks.

One of these is Block B, set in the winter and spring of 1932–1933, which consists of the varieties York Imperial, Gallia Beauty, Jonathan, Staymared, Golden Delicious, and Starking, all on the Malling II rootstock. A previous report (2) gives a fuller description of Block B, a planting cooperative with the Bureau of Plant Industry, United States Department of Agriculture, especially during the period preceding the removal of the fillers on Malling IX. As planted there were 21 trees of a variety on Malling II arranged in three adjacent rows of seven trees each. Except in the case of Staymared, at least one tree of each variety was missing in 1945. None of the losses, however, is chargeable to any inherent weakness in the Malling II rootstock.

Table I presents the average total yield per tree for all varieties in Block B from the initiation of bearing through the 1944 season. The average trunk circumferences are included.

TABLE I—Performance of 12-Year-Old Apple Trees on the Malling II Rootstock. Block B, Kearneysville, West Virginia

Variety	Average Total Yield per Tree (Pounds)			Average Circumference (Mm)	
	N*	M	S. E. M.	M	S. E. M.
York Imperial	16	386	± 29.37	549	± 14.86
Gallia Beauty	17	654	± 44.97	451	± 10.12
Jonathan.... .	19	636	± 29.71	470	± 8.70
Staymared . .	21	731	± 59.99	503	± 10.31
Golden Delicious .	20	918	± 50.96	538	± 8.39
Starking . .	20	484	± 61.96	593	± 11.34

*N = Number of trees. M = Average yields in pounds or circumferences in Mm. S. E. M. = Standard error of the means.

The second of these small plantings is Block C. These trees, which were set in the spring of 1932, consist in part of two rows of Red Rome/Malling I and four rows of Red Rome/Malling XIII. Each row is 14 trees long. The Red Rome trees were arranged in two plots, each of which contained one row of Red Rome/Malling I and two rows of Red Rome/Malling XIII. A previous report (1) may be consulted for further details.

Table II gives the average total yield per tree for Red Rome on both rootstocks from the beginning of bearing through the 1944 harvest. Table III presents the average trunk circumferences for the two groups after the 1944 season.

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TABLE II—AVERAGE TOTAL YIELDS IN POUNDS PER TREE OF 13-YEAR-OLD RED ROME APPLE TREES ON MALLING ROOTSTOCKS. BLOCK C, KEARNEYSVILLE, WEST VIRGINIA

Rootstock	N*	M	S. E. M.	D	S. E. D.
Malling I	26	1,198	± 54.99	196	68.08
Malling XIII ..	53	1,394	± 40.13	—	—

*N = Number of trees. M = average total yields in pounds per tree. S.E.M. = Standard error of the means. D = Difference. S. E. D. = Standard error of the difference.

TABLE III—AVERAGE TRUNK CIRCUMFERENCES IN MILLIMETERS OF 13-YEAR-OLD RED ROME APPLE TREES ON MALLING ROOTSTOCKS. BLOCK C, KEARNEYSVILLE, WEST VIRGINIA

Rootstock	N*	M	S. E. M.	D	S. E. D.
Malling I.	26	479	14.73	81	15.86
Malling XIII ..	53	560	5.88	—	—

*N = Number of trees. M = Average trunk circumferences in Mm. D = Difference. S. E. D. = Standard error of the difference.

DISCUSSION

Block B:—The Malling II rootstock has been very satisfactory for producing trees with good yields and of considerably less than standard size with four of the six varieties, Jonathan, Staymared, Starking, and Golden Delicious; the yield of the latter has been especially striking considering the reduced tree size.

York Imperial/Malling II has resulted in trees of very irregular size and with poor yields, the lowest of the six varieties; some possible evidence of uncongeniality has been observed.

At Kearneysville, Gallia Beauty, which bears early and heavily under any reasonable conditions, does best on a rootstock inducing very vigorous growth; no dwarfing is necessary or desirable with trees of this variety under the conditions existing in the Shenandoah Valley (3).

Thus far, Malling II has been the most promising rootstock of that series under test in West Virginia.

Block C:—This group of trees is interesting chiefly as it has shown how markedly certain rootstocks may affect the relative age of bearing of the scion. It also has demonstrated the fact that relative positions or ranks according to yield of various rootstocks worked to the same variety may shift radically in the space of a few years.

For example, the trees of Red Rome/Malling I bore their first heavy crop in 1937, their sixth year in the orchard. As a direct consequence, a large proportion of them leaned so far that it was necessary to pull them to an upright position then to wire and stake the trees (1). That same year, the visibly larger trees of Red Rome/Malling XIII bore very little.

Through 1939, their eighth season, the Red Rome/Malling I combination had produced significantly more than Red Rome/Malling XIII, although the latter were considerably larger. After 1943, the 12th season, the larger trees on Malling XIII were forging ahead in yields but were not significantly superior. The 1944 yields have put

the combination Red Rome/Malling XIII above Red Rome/Malling I; so far as it is possible to judge by the trunk circumferences and by the relative size of the tops, the trees on Malling XIII might be expected at least to hold their lead.

Thus far, neither Malling I nor Malling XIII show any promise as apple rootstocks under the conditions prevailing at Kearneysville. Red Rome, like Gallia Beauty, tends to bear too soon. Rootstocks resulting in any degree of dwarfing with either of these varieties are not desirable in the Cumberland-Shenandoah Region.

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Propagation of Peaches from Softwood Cuttings[1]

By George W. Cochran, *Cornell University, Ithaca, N. Y.*

Peach trees are propagated by budding the desired variety onto a seedling rootstock. In the course of stone fruit virus investigations, it became desirable to use own-rooted clones of commercial varieties of peaches. Many attempts that have been made to root varieties of deciduous fruits from cuttings have not been overly successful, though it has been shown that cuttings of young seedlings of deciduous fruits may be rooted in this way (3). Nevertheless, experiments were begun in the fall of 1943 with the objective of developing a successful method of propagating peach varieties by cuttings.

Results with Peach Seedlings in 1943 and 1944

In a preliminary experiment in August and September, 1943, an attempt was made to root untreated, leafy, terminal twig cuttings in a sand medium. The plant material was from seedlings grown from seed secured in Tennessee. A few of the cuttings rooted but most of them died and decayed.

Because of the prevalence of rotting in this first experiment, a second was begun on November 17 to test the effectiveness of various fungicidal dusts in protecting the cuttings from rotting organisms. The untreated cuttings in this experiment did not rot and they, with most of the fungicidal-treated cuttings, rooted 80 to 100 per cent. Three of the treatments, "New Improved Ceresan" (5 per cent ethyl mercury phosphate), and red and yellow copper oxides were so toxic at the concentrations used that they killed the cuttings. The other fungicidal dusts, "Fermate" (ferric dimethyldithiocarbamate), zinc dimethyldithiocarbamate, manganese dimethyldithiocarbamate, zinc oxide, "Ansul Dust" (6 per cent oxymethlyene), "Semesan Jr." (12 per cent hydroxymercuricresol), "Barbak-C" (8 per cent mercuric phenyl cyanamide and 2.5 per cent cadmium oxide), "Arasan" (50 per cent tetramethylthiuram disulfide), "Thiosan" (50 per cent tetramethylthiuram disulfide), and "Spergon" (tetrachloro-para-benzoquinone) were apparently non-toxic and seemed neither to inhibit nor to promote rooting. While no conclusive results were secured as to the value of these materials in protecting cuttings from rotting, nevertheless because of the non-toxic, finely divided nature of Fermate and its ease of procurement, it appeared promising for further trial.

A third experiment was conducted to test the influence of root-stimulating hormones on the rooting of peach cuttings. In this experiment, mixtures of hormones and Fermate were prepared and used instead of the standard talc-hormone powders. The following growth substances were combined with the Fermate: gamma-(indole 3)-n-butyric acid, commercial napthaleneacetic acid, 4-chloro-phenoxy-

[1]The term "softwood cutting" as used in this paper is defined as a portion of any leafy shoot of the current season's growth of wood. A "hardwood cutting" is defined as a portion of a dormant leafless shoot.

acetic acid, beta-napthoxyacetamide, indole-3-acetic acid, and beta-napthoxyacetic acid. The first five chemicals were used in concentrations of 1, 3, 8, and 12 mg per gram of Fermate. Cuttings were dipped in these chemicals and then placed in flats of sand on January 11. Six cuttings were treated with each concentration of the hormone-fungicide mixture. Six lots of six cuttings each were treated only with Fermate dust, and three lots of six cuttings each were placed in the rooting sand without any special treatment. Cuttings consisted of 4- to 6-inch terminal portions, bearing six or seven leaves and taken from green succulent twig growth of 1-year-old seedling trees.

The records from this experiment are summarized in Table I. Indole butyric acid-Fermate and napthaleneacetic acid-Fermate treatments in the concentrations tested produced the most rapid and most extensive rooting. The effectiveness of the two hormone-Fermate mixtures increased with an increase in their concentration up to 12 mgs of hormone per gram of Fermate. Concentrations of 4-chloro-phenoxyacetic acid above 1 mg per gram of Fermate definitely inhibited root production.

Eighteen of the 22 hormone-Fermate treatments produced 100 per cent rooting within 7 weeks. All of the cuttings treated with indole butyric acid, commercial napthaleneacetic acid, indoleacetic acid, and beta-napthoxyacetic acid-Fermate mixtures rooted. The Fermate-treated cuttings showed 89 per cent rooting, and the untreated cuttings showed 100 per cent rooting after 7 weeks. The root development of untreated, Fermate-treated, and Fermate-indole butvric acid-treated cuttings 3 weeks after treating is shown in Fig. 1. It was noticed that non-terminal leafy cuttings rooted as well as terminal cuttings. Actively growing terminal cuttings and non-actively growing terminal cuttings rooted with equal facility.

One hundred cuttings were taken from greenhouse-grown seedlings on July 10. Lots of 25 cuttings each were treated with the same indole butyric acid-Fermate powders that were used in the experiment of January 11. The cuttings were treated and handled in the same manner as on January 11; however, the flats were placed out-of-doors under shade. All of the cuttings dropped their leaves and died. Only two of the cuttings initiated roots.

Results with Hardwood Cuttings of Varieties of Peaches in 1944

Numerous attempts were made throughout 1944 to root cuttings taken from orchard trees of commercial varieties of peaches. Starting in January, cuttings were taken at intervals of 2 or 3 weeks throughout the year. All hardwood cuttings were planted in flats of moist sand and held in the greenhouse at a temperature of 65 degrees F. The sand was watered daily from above.

On January 5, 130 Elberta and 130 Rochester cuttings (4-inch sections cut from dormant twigs) were treated by dipping the bases in hormone powders. Powders used were Hormodin Nos. 1, 2, and 3; indole butyric acid and napthaleneacetic acid-Fermate mixtures (con-

TABLE I—EFFECT OF VARIOUS CONCENTRATIONS OF DIFFERENT ROOTING HORMONES COMBINED WITH FERMATE AND APPLIED AS POWDERS TO THE BASES OF SOFTWOOD CUTTINGS OF PEACH SEEDLINGS, 1944

Mg of Hormone Per Gram of Fermate	Extent of Rooting After Three Weeks Average per Cutting		Per Cent of Cuttings Rooted After:		Per Cent of Cuttings Showing Terminal Shoot Growth After	
	No. Roots	Combined Length of Roots (Cm)	3 Weeks	7 Weeks	3 Weeks	7 Weeks
		Indolebutyric Acid and Fermate				
1	9	36	100	100	0	100
3	11	62	83	100	33	67
8	12	58	100	100	33	100
12	17	105	100	100	100	83
		Naphaleneacetic Acid and Fermate				
1	8	26	83	100	0	100
3	16	68	100	100	67	83
8	14	55	83	100	17	67
12	17	51	100	100	0	83
		Beta-napthoxy-acetamide and Fermate				
1	5	12	67	83	0	83
3	16	44	100	100	0	100
8	10	9	67	83	0	50
12	25	33	100	100	0	100
		4-Chlorophenoxy-acetic Acid and Fermate				
1	8	17	100	100	0	100
3	0	0	0	50	0	50
8	2	0.3	50	100	0	17
12	0	0	0	33	0	17
		Indole-3-acetic Acid and Fermate				
1	4	5	83	100	0	83
3	5	12	100	100	33	100
8	11	32	100	100	0	83
12	9	29	100	100	0	67
		Beta-napthoxyacetic Acid and Fermate				
1	4	4	100	100	0	100
3	4	4	83	100	0	83
		Fermate				
0	4	9	83	100	50	100
0	3	5	67	83	0	50
0	3	6	100	100	0	100
0	6	13	83	100	0	83
0	4	13	100	100	17	67
0	3	5	50	50	0	17
		Average of Fermate Treatments				
0	4	8	80	89	11	69
		Checks—No Fermate or Hormones				
0	3	3	100	100	0	67
0	7	15	100	100	0	100
0	5	13	83	100	0	33
		Average of Untreated Checks				
0	5	10	94	100	0	67

centrations of 1, 3, 8, and 12 mg of hormone per gram of Fermate); and Fermate. Ten cuttings of each variety were given each treatment, and 10 were untreated.

Two weeks later, January 19, more Rochester and Elberta cuttings were taken from the same orchard trees. These cuttings were placed

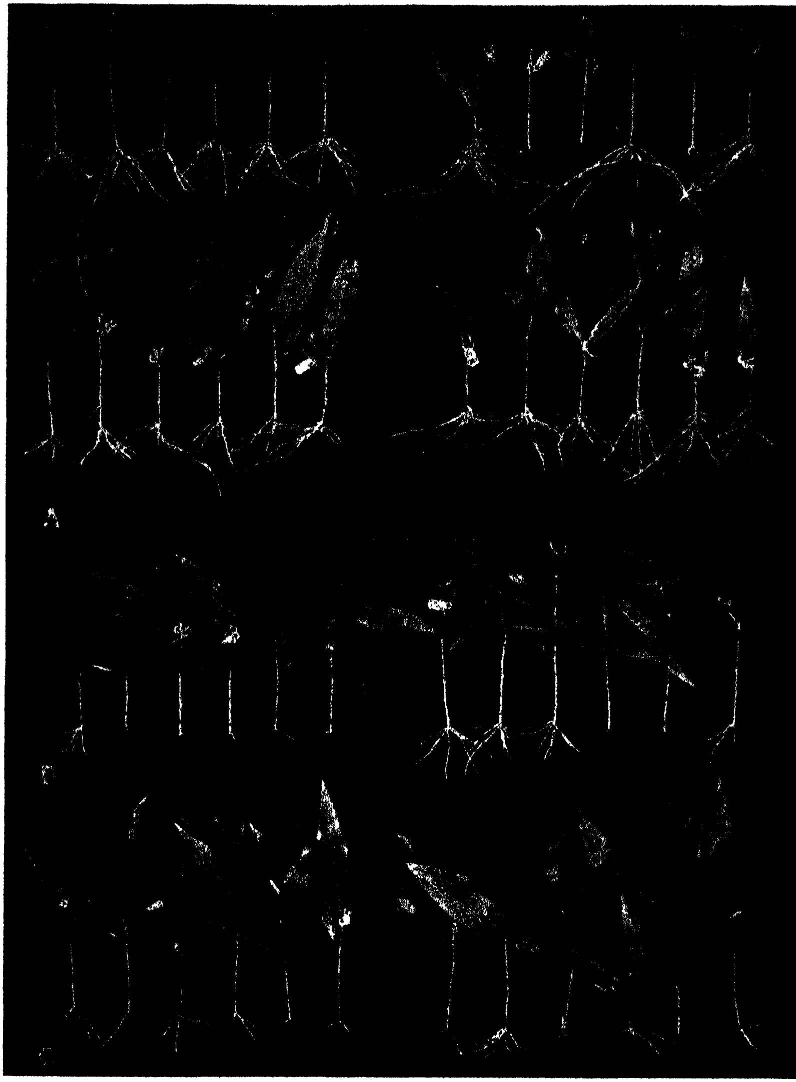

FIG. 1. Root development of softwood cuttings 3 weeks after removal from greenhouse-grown seedling peach trees. Groups of six cuttings, left to right from top to bottom. A, treatments of 1, 3, 8, and 12 mg indole butyric acid per gram of Fermate. B, check cuttings receiving no chemical treatments. C, cuttings treated with Fermate dust only.

in a glass evacuation chamber and were covered with a 10 per cent sucrose solution. The chamber was connected to a suction pump which created a negative pressure of 55 cm of mercury. The air withdrawn from the cuttings at reduced pressures was replaced by the sugar

solution. After a 15-minute vacuum treatment, the cuttings were removed and washed thoroughly in tap water. They were then given the same powder treatments that were used on January 5. Ten cuttings of each variety were given each treatment, and 10 were treated with only the sugar solution.

On February 7, Rochester and Elberta cuttings from the same sources were again given vacuum treatments similar to that given on January 19. Ten cuttings of each variety were given the 15-minute vacuum treatment while submerged in 10 per cent sugar solutions containing 400, 4400, 8400, 16400, and 32400 ppm of indole butyric acid.

On February 17, 252 Rochester and 252 Elberta hardwood cuttings were divided into seven lots of 72 cuttings, each lot containing 36 Rochester and 36 Elberta cuttings. Six of the lots were given different preliminary vacuum treatments, and one lot was not vacuum treated. The solutions used in the 15-minute vacuum treatments were as follows: distilled water 100 ppm vitamin B_1, distilled water 1000 ppm vitamin B_1, distilled water 2000 ppm vitamin B_1, 10 per cent sugar 100 ppm vitamin B_1, 10 per cent sugar 1000 ppm vitamin B_1, and 10 per cent sugar 2000 ppm vitamin B_1. The lots were washed in tap water following the vacuum treatments. Each of the seven lots was then subdivided, first by separating the varieties, and then by dividing each variety into six lots of six cuttings each. These smaller lots of six cuttings were each given a hormone powder treatment. Fermate-indole butyric acid powders containing 12, 18, 25, 35, and 50 mg of hormone per gram of Fermate were used for these secondary treatments.

The experiment of January 5 was repeated on March 2 with a slight modification. Half of the cuttings given each treatment were watered with a 2000 ppm solution of vitamin B_1 10 days after the hormone treatments. The other half of the cuttings received no vitamin B_1.

On March 21, the experiment of January 19 was repeated and modified by watering half of the cuttings of each treatment with 2000 ppm vitamin B_1 solution 10 days after the hormone treatments were applied.

The treatment of January 5, using various hormone powders, was repeated again on April 15. No vitamin B_1 was used.

All treatments applied to hardwood cuttings gave negative results. Leaf buds usually developed into shoots ½ to ¾ of an inch in length and then wilted, and the cuttings died.

Results with Softwood Cuttings of Varieties of Peaches in 1944 and 1945

Early Summer Hormone Treatments:—Experiments with softwood cuttings were begun in May as soon as the shoots were 3 to 4 inches long, using the following varieties: Elberta, Early Elberta, Rochester, Halehaven, South Haven, Carmen, Belle, J. H. Hale, Vedette, Veteran, Valiant, and Mikado. Cuttings were treated, placed in flats of sand in the greenhouse, shaded by two thicknesses of cheese

cloth, and were sprinkled with water several times daily. They were made 3 to 4 inches long so that 1 inch at the base could be inserted in sand, leaving a 2- to 3-inch portion bearing leaves above the rooting medium. It was found desirable to cut off the leaf tips at right angles to the midrib leaving only a stubby basal portion 3 to 4 cm long attached to the stem. Usually two or three leaf stubs were left on each cutting. This trimming of the leaves avoided excessive overlapping and prevented contact of the leaves with the rooting medium. In this way, leaf decay caused by fungi and bacteria was largely avoided.

During May and June, cuttings of all of the varieties were treated with the same hormone powders that were used in the first hardwood cutting experiment of January 5. Also, cuttings of all the varieties were treated by dipping the bases in a 50 per cent solution of ethyl alcohol containing 2 mg of indole butyric acid per ml of solution. Treating times were varied from an instantaneous dip to 3 minutes when this alcoholic solution was used. The cuttings remained turgid for 2 or 3 days after treatment, after which wilting became gradually perceptible. One week after the cuttings were made wilting was usually pronounced, the stems were shriveling, and the leaves were beginning to fall. At this time bases of the cuttings were dying. Not any of the cuttings rooted which were treated during May or June.

Aseptic Method:—During July, attempts were made to root cuttings under aseptic conditions in the laboratory. Leaf-bud cuttings were made of all 12 varieties. Entire cuttings were dipped into 70 per cent alcohol and then held in a 25 per cent Clorox solution for 1 minute. Mixtures of indole butyric acid in lanolin containing 10, 50, 100, 200, 500, and 1000 ppm of the hormone were sterilized and applied to the bases of the cuttings which were then transferred aseptically to sterile petri dishes containing a sterile 2 per cent sucrose solution. The leaves were floated with the dorsal surface upward. The petioles were bent backward so that the small portion of the hormone-treated stem was pressed firmly against the cover of the dish and was not in contact with the sugar solution. The petri dishes were placed in weak light. None of the cuttings rooted, but many calloused heavily. They were discarded after holding for 6 weeks.

In another experiment, actively growing tips of Elberta and Rochester shoots were selected. These were dipped in 70 per cent alcohol and then placed for 1 minute in a solution of mercuric chloride (1 part of mercuric chloride to 1000 parts of distilled water). While in the mercuric chloride bath, all leaves longer than 1 cm were removed and a fresh basal cut was made, leaving a stem tip 1 cm long bearing rudimentary leaves. This tip was immediately transferred to a sterile tube of agar, using sterilized forceps. Tips dissected and surface sterilized in this manner were also treated with indole butyric acid dissolved in 50 per cent ethyl alcohol. The concentrations of indole butyric acid varied from $^1/_{10}$ mg per ml to 2 mg per ml. Tips were dipped in the alcohol solutions after taking from the 1-minute mercuric chloride bath. None of the tips rooted.

Another lot of leaf-bud cuttings of all 12 varieties was treated for varying lengths of time (10 seconds to 2 minutes) by dipping the

stem bases in a 50 per cent solution of ethyl alcohol containing 2 mg of indole butyric acid per ml. The apical portions of the leaves were removed, leaving stubby leaf bases attached to the short stem sections. The bases of these cuttings were inserted in a firm nutrient agar that had been poured in halves of petri dishes. Since carbohydrates had not been added to the agar, no effort was made to provide aseptic conditions. About 50 cuttings were placed in each dish. The dishes were held in large moist chambers where a relative humidity of 100 per cent was maintained. The cuttings received a limited amount of natural light from nearby windows. These cuttings were examined and discarded 2 months after treatment; none had rooted.

Aerated-water Method:—A large metal tank was equipped with carbon aerators as described by Smith (9). Cuttings were suspended by a rack made of ½-inch mesh galvanized screen. The tank was held in the laboratory in bright natural light. On July 5, the bases of 1,000 Elberta cuttings were treated for 1 minute in a 50 per cent solution of ethyl alcohol containing 2 mg of indole butyric acid per ml. These cuttings wilted and the leaves abscissed even though the bases were held in aerated water that was changed daily. The bases of a few cuttings swelled slightly, but none rooted.

Mid- and Late Summer Hormone Treatments:—The first of July, all of the flats of sand being used in the cutting investigations were moved from the greenhouse to a cool outside spot that was shaded by natural vegetation throughout the day. The experiments of April and May were repeated with negative results. Leaf abscission increased as the season progressed, and the cuttings continued to wilt and die.

Cuttings of all 12 varieties were placed in flats on July 15, and the foliage and stems were then sprayed using a range of different concentrations of indole butyric acid in water. Sprays of 1, 10, 50, 100, and 150 ppm of indole butyric acid were applied to cuttings of each variety. None of the cuttings rooted.

On August 2, 200 selected twigs of Elberta trees were sprayed with a water solution of indole butyric acid (150 ppm). Cuttings were removed from these sprayed branches at 2-day intervals for a period of 2 weeks and placed in sand without further treatment. None of 500 cuttings initiated roots.

On September 3, more cuttings of all 12 varieties were made and were treated with indole butyric acid. The concentrations used ranged from 0.1 to 250 ppm. The hormone was dissolved in a mixture of equal parts of "Carbowax 1500" and water. The bases of the cuttings were dipped in these solutions and the cuttings were planted in flats of sand. Cuttings treated with 50 and 100 ppm of indole butyric acid enlarged slightly at the base but did not root.

The experiment of July 15 was repeated on September 15. Sprays having the same concentrations of indole butyric acid in water were applied to the foliage of 20 cuttings of each of the varieties. However, 5 grams of "Carbowax 1500" was added to each 100 ml of the spray mixtures. All of the flats were moved into the greenhouse on September 20. None of the cuttings rooted.

Fall Hormone Treatments:—Leafy cuttings taken during October and November responded more favorably to hormone treatments. Five lots of 1000 leafy Rochester cuttings were taken in October. One lot was untreated, and the bases of the cuttings in another lot were treated for 1 minute in 50 per cent alcohol containing 2 mg of indole butyric acid per ml of solution. The bases of a third lot were treated with an indole butyric acid-Fermate powder containing 12 mg of hormone per gram of Fermate. The bases of a fourth lot were treated with a similar powder containing 18 mg of hormone per gram of Fermate; while the bases of a fifth lot were treated with a similar powder containing 25 mg of hormone per gram of Fermate. The same treatments were given to five lots each containing 2000 leafy Elberta cuttings also taken during October.

Nearly 100 per cent of the treated cuttings calloused and initiated roots. The untreated cuttings did not callous as heavily as the treated, and less than 5 per cent of the untreated cuttings initiated roots. Leafless cuttings taken in early November after killing frosts had defoliated the trees rooted as well as leafy cuttings taken 2 weeks earlier. The leafy cuttings taken during October and November dropped their leaves 3 to 4 weeks after they were cut. They did not break dormancy, and consequently the newly initiated roots continued linear growth until the carbohydrate reserves were depleted. At this stage, fungi attacked and killed the weakened cuttings.

Cuttings taken late in November and in December, which were really hardwood cuttings, failed to initiate roots in response to any treatment.

Microscopic Examination of Wilted Cuttings:—In spite of frequent watering, which maintained a high moisture level in the rooting medium, wilting was perceptible 4 to 5 days after cuttings were made and became progressively greater each day until all leaves dropped. Microscopic studies using the technique described by Rawlins (8) demonstrated wound gum plugging the large vessels. In 2-day-old cuttings, only a few of the vessels were plugged; in 4-day-old cuttings, 10 per cent were filled with gum; in 10-day-old cuttings, about 50 per cent were plugged; and in 2- to 3-week-old cuttings, 70 to 90 per cent of the vessels were plugged. Fresh cuttings had no wound gum in the vessels.

Mist Method:—Since the cuttings were unable to obtain enough water from the rooting medium, the continuous mist method was tried, as used in various modifications by Raines (6–7), Gardner (2), Fisher (1), Stoutmeyer (10), Pridham (5), and Gossard (4) in attempts to root leafy cuttings. Greenhouse propagation benches containing sand were enclosed with a commercial cellophane cloth. Atomizers were placed 12 to 14 inches above the sand within the enclosure. When in operation, the atomizers filled the enclosed propagating frame with a heavy fog.

In January 1945, 28 three-year-old budded peach trees were brought in from out-of-doors and forced in the greenhouse. Half of the trees were of the variety Rochester, and the other 14 were Elberta.

Leafy shoots from these trees were used in experiments during March, April, and May.

More than 500 cuttings were held in the continuous mist after being treated with various concentrations of indole butyric acid. Both liquid and powder treatments induced rooting, providing the concentrations were varied according to the hardness of the cuttings. Indole butyric acid-Fermate powders gave excellent rooting. Tips of fast growing shoots were very soft and succulent and were injured by concentrations higher than 0.5 mg of indole butyric acid per gram of powder, while cuttings taken from the harder basal part of 10- to 14-inch twigs were rooted by using concentrations as high as 12 mg of indole butyric acid per gram of powder. A 1-minute liquid treatment in 50 per cent alcohol containing 1 mg of indole butyric acid per ml was effective in rooting cuttings of medium hardness. In a few cases, untreated cuttings rooted but never as well as hormone-treated cuttings. Cuttings from Elberta and Rochester responded equally well to the treatments, and the roots were identical in size, shape, vigor, and position to those initiated by cuttings from seedlings.

The root development of Elberta cuttings at 3 and 9 weeks after treating may be seen in Fig. 2. Four to 5 days after treatment, the first evidence of rooting appeared as slight bumpiness near the bases of the cuttings. A week later, small root tips emerged from the sides

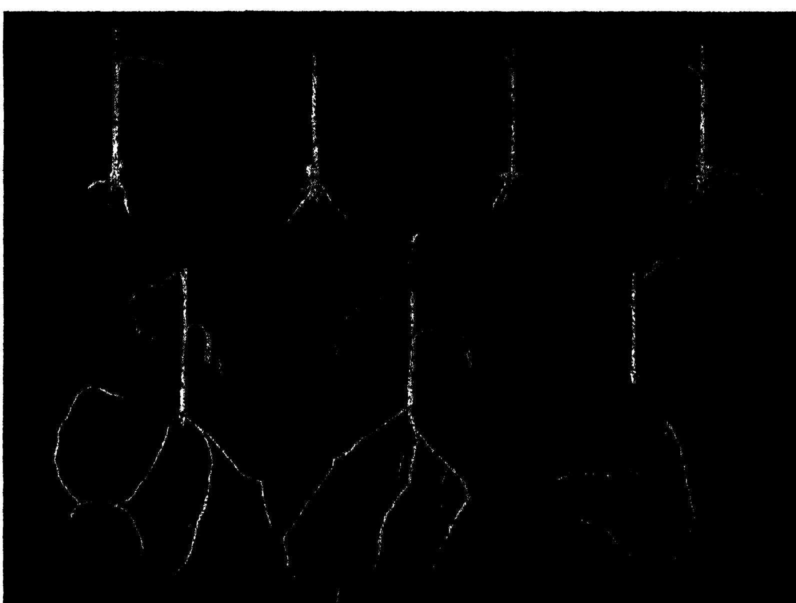

Fig. 2. Root development of softwood cuttings of Elberta treated with a powder containing 12 mg of indole butyric acid per gram of Fermate. Cuttings in the upper row show the stage of development 3 weeks after treating. Those in the bottom row show the root development 9 weeks after treating.

of the stems near the bases. The bases sometimes calloused. In cases of vigorous rooting, there was usually no callousing, and in cases of heavy callousing, rooting was usually retarded. The most desirable cuttings from the standpoint of rooting were those at least 3 to 4 mm in diameter and 8 to 10 cm in length. Succulent tips did not root as well as the middle or basal portions.

Rooted cuttings were usually removed from the propagation bench 1 month after treatment when the roots were 3 to 4 cm long. They were carefully potted in a light, fertile greenhouse soil. The leaf area was reduced to less than 2 sq cm and the plants were shaded until they had become established.

Summary

In preliminary experiments during the winter of 1943–1944, rapid and extensive rooting was secured from softwood cuttings of greenhouse-grown seedling peach trees. The application of hormones was not essential for the initiation and development of roots during this season. Only 2 per cent of the softwood cuttings taken from greenhouse-grown seedlings in July rooted in response to the same treatments that gave 100 per cent rooting of similar material during the winter.

All treatments given softwood cuttings of commercial varieties prior to October 1 in 1944 failed to induce rooting. Leafy cuttings treated in October and early November rooted but died soon after rooting. Hardwood cuttings taken immediately after killing frosts had defoliated orchard trees rooted in response to hormone treatments and then died. The failure of softwood cuttings to root during the summer of 1944 was believed to have been caused by water deficits created by a plugging of the xylem vessels with wound gum.

In 1945, propagation benches were enclosed and equipped with atomizers that maintained a continuous mist in the air above the propagating medium. Softwood cuttings of the varieties Elberta and Rochester taken from 3-year-old trees forced in the greenhouse were rooted on five different occasions during March, April, and May by treating with indole butyric acid and then holding in continuous mist. The results suggest that the method may also be applied to outdoor-grown cuttings.

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Studies in Preservation of Eastern Freestone Peaches

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THE present paper is a condensation of certain phases of reports previously published in greater detail in technical journals. For full details and a discussion of other related work the reader is referred to the original articles (1, 2, 3).

Sixty-two varieties of peaches grown in the varietal orchards of the Division of Fruit and Vegetable Crops and Diseases at the Bureau of Plant Industry Station, Beltsville, Maryland, in the season of 1942 were tested for canning, dehydrating, and making into preserves. The varieties employed were selected from a considerably larger number available with the intent of including, insofar as they were present in the collection and in fruit, all yellow-fleshed freestone varieties of any commercial importance and especially all recent introductions showing promise of becoming important. Three white-fleshed varieties and five cling and semi-cling types were included for purposes of comparison.

The trees from which fruit used in the study was obtained were 4 to 11 years of age, were in healthy, vigorous condition, and were bearing fair-to-heavy crops. For the great majority of the varieties the fruit used was a composite sample from four trees, in a few cases from two trees only. The amount of fruit of a variety available was such that a sample of several bushels could be obtained, either at a single picking or two successive pickings. The bulk sample was subdivided into three portions, one for canning, another for dehydrating, and the third for making into preserves. The portions employed for canning and preserve making were at the stage of ripeness found by previous experience to be optimum for these purposes, namely 4 to 5 days after the stage at which fruit is picked for rail shipment to distant markets, or 24 hours before most persons would term the fruit "prime eating ripe." The portion used for the dehydration work was larger and could usually be separated into three subsamples, one firm-ripe, the second at the optimum stage for canning, and the third soft-ripe.

The season was a very favorable one from the blooming period up to about July 20, with adequate rainfall, more than the normal percentage of sunshine, and above-normal temperatures. The entire harvest period, July 15 to September 12, was distinctly unfavorable. Mean temperatures were persistently above-normal, and precipitation occurred on 33 of the 59 days to a total of 15.40 inches, which is twice the normal. There were only 7 uninterruptedly clear days, and the combination of persistent cloudiness and frequent rainfall resulted in abnormally high humidity over the entire ripening period. These conditions were especially pronounced in the period July 21 to August 25, in which the majority of the varieties ripened. As a consequence, the crop as a whole had somewhat less color than normal, and was fair-to-good in quality though not high in flavor. There were con-

siderable differences between varieties ripening on the same date in the degree to which they were affected, some showing varying degrees of softening and waterlogging and dilution or deficiency of flavor, while these were not apparent in others. The general effect of the conditions of the ripening period was to reduce a crop which had promised to be of exceptionally fine quality to one which was average or slightly below average in sweetness and flavor. It is believed that this is not disadvantageous for the present purpose, and that the results of the work more nearly represent what may fairly be expected of the varieties than would have been the case if the material used had been of better-than-average quality.

The fruit used for canning was selected for uniformity in ripeness, the stage used being that regarded as optimum for the purpose. It was peeled by immersion in 10 per cent lye solution at 140 degrees F, washed in running water, halved, stoned, packed into No. 3 cans, covered with 50 per cent sugar sirup previously heated to 175 degrees F, exhausted 10 minutes, sealed, processed in flowing steam for 35 minutes, and rapidly cooled in an airblast from a fan. The canned samples were stored at 70 to 75 degrees F for approximately 6 months before examination and scoring (1). The fruit used for making preserves was usually a portion of the lot peeled for canning, hence was at the same stage of ripeness. It was stoned, sliced lengthwise into slices ¼ to ⅜ inch in thickness, mixed with sugar in the proportions 52.5 per cent fruit and 47.5 per cent sugar, boiled with continuous gentle stirring to a concentration of 68 per cent solids, filled hot into sterile glass containers, sealed, cooled, and stored under the same conditions and for the same period as the canned samples (2).

Fruit of nearly all the varieties was dehydrated in two forms, peeled and unpeeled, and at three stages of ripeness, firm-ripe, canning-ripe, and soft-ripe (3). The lots dried without peeling were washed, halved, spread on trays, sulfured at the rate of 6 pounds per ton of fruit for 3 to 4 hours at 85 to 95 degrees F, and transferred to the drier. Peeled lots were lyepeeled and sulfured at the same rate but for only 1 to 1½ hours before placing in the drier. (Subsequent observation of the material in storage and repetition of the work with a few varieties in the following year showed clearly that the sulfuring treatment, while adequate for some varieties, was insufficient for many or most, and that the time of exposure might have been doubled with benefit of the material in improving color and postponing deterioration). Drying was begun at 140 to 145 degrees and completed at 120 to 125 degrees F. The fruit was removed from the dehydrator with a residual moisture content of approximately 17 to 18 per cent and held in a dry room at 75 degrees F for 2 weeks to equalize distribution of moisture. Portions were then transferred to sealed containers, one set of which was stored at 50, the other at 70 degrees F. Other portions were stored in cloth bags at these temperatures. The period of storage prior to examination and grading was 6 months.

In the final examination, each of the samples of canned fruit and of preserves was separately scored on color, texture or consistency, degree of disintegration of pieces, and palatability and flavor. In

averaging the ratings on the various factors to obtain the final score, twice as much weight was given to the rating on palatability and flavor as to that on other factors. In the dehydrated material, peeled and unpeeled samples at each of the stages of ripeness used were graded separately, both in dry condition and after refreshing and cooking. The factors considered in grading the cooked samples were those employed in grading the canned and preserved samples, but somewhat greater weight was laid upon quality of yellow color of the flesh, amount of red pigment in the flesh and stone cavity, and presence or absence of browning in the flesh. As a general rule, the fruit dried without peeling ranked lower than the corresponding peeled sample in color and appearance, texture and, in many cases, in flavor. This was due to fading of yellow and darkening or purpling of red color in the skin, and to its toughness and astringency or bitterness. The heavy pubescence of many varieties, which could be only very imperfectly removed by washing, was also objectionable. In consequence of these defects, varieties ranked as excellent in peeled form rated no better than good as unpeeled, those rating as good to fair in peeled form were in most cases poor-to-very-poor in unpeeled condition. Drying without peeling is consequently advised against as sacrificing quality in the product. Drying at the early-ripe stage, whether peeled or unpeeled, results in an inferior product; best appearance and quality are obtained in fruit dehydrated at the optimum stage of ripeness for canning.

The final scores for canned, preserved, and dehydrated products of all the varieties are assembled in Table I. The ratings are those given the samples prepared from fruit at the optimum stage of ripeness. Instead of numerical scores, six ratings ranging from excellent through very good, good, and fair to poor and very poor have been employed.

It is immediately obvious from inspection of the table that there is no consistent correlation between quality of the preserve made from a variety and that of its canned or dehydrated product. Varieties rated as excellent for preserves are distributed over all grades from excellent to very poor when canned, and the reserve is also true. Quality in dried form bears very little relation to quality for canning or preserve making. The physical factors considered in determining quality in the processed fruit are the same whatever the method employed for its preservation, but the treatments employed in preparation of the material in these different forms are so widely different that the same raw material may respond very differently to them. Varieties prone to discolor in air may become objectionably darkened when dehydrated but have excellent color when canned. Firm-fleshed varieties may be of excellent texture when canned but objectionably tough or leathery when preserved or dried, while soft-textured varieties may retain shape very well in canning or drying but disintegrate badly when preserved. Presence of red pigment may increase attractiveness of a preserve but cause purplish discoloration in canned or dried fruit. Flavor is very much less subject to modification by the various treatments than are color and texture, and it is differences in

TABLE I—COMPARATIVE QUALITY OF PRODUCTS OBTAINED FROM 62 VARIETIES OF PEACHES BY CANNING, PRESERVING, AND DEHYDRATING PORTIONS OF THE SAME LOT OF MATERIAL

Variety	Type*	Quality of Product When Preserved By:			
		Canning	Preserving	Dehydrating	
				Peeled	Unpeeled
Barnard	YFM	P**	G to VG	F	
Belle (Belle of Georgia)	WFM	P	P	P to VP	P
Brackett	YFM	F to G	G to VG	F	P
Canadian Queen	YFM	E	G to VG	VG	—
Candoka	YFM	F to G	P	P to VP	—
Chili	YFM	--	VG	F	—
Cumberland	WFM	VP	P	P to VP	VP
Early Crawford	YFM	F	P	F	P
Early Elberta	YFM	E	E	VG	G
Eclipse	YFM	VG	E	G	G
Elberta	YFM	F to G	G to VG	G	G
Engle	YFM	F to G	P	VG	G
Fair Beauty	YFM	—	G to VG	P to VP	P
Fay Elberta	YFM	F to G	G to VG	VG	G
Fertile Hale	YFM	VG	G to VG	VG	G
Fisher	YCSM	VG	P	F	—
Gage (Gage Elberta)	YFM	P	G to VG	VG	G
Globe	YFM	VG	E	G	F
Gold Drop	YFM	—	G to VG	E	G
Golden Globe	YFM	F to G	G to VG	P to VP	—
Golden Jubilee	YFM	F to G	P	G to VG	G
Halberta	YFM	P	G to VG	G	F
Halehaven	YFM	VG	G to VG	VG	F
Hiley	WFM	VP	P	P to VP	VP
Ideal	YFM	F to G	E	VG	G
July Elberta	YFM	E	P	VG	G
Kalamazoo	YFM	VG	G to VG	VG	G
Kette	YFM	P	G to VG	G	F
Krummel	YFM	VP	G to VG	F	P
Late Crawford	YFM	F to G	G to VG	F	P
Late Elberta	YFM	F	G to VG	F	G
Lemon Cling	YCNM	E	G to VG	F	VP
Lemon Free	YFM	P	G to VG	VG	—
Lovell	YFSM	F to G	G to VG	E	G
Mark Late	YFM	P	G to VG	F	—
Markham Cling	YCSM	VP	P	P to VP	—
Massasoit	YFM	VG	E	G	--
Maxine	YFM	P	G to VG	P to VP	P
Muir	YFSM	—	E	VG	F
Newcomb	YFM	F to G	P	P to VP	VP
Newday	YFM	VG	P	P to VP	—
Oriole	YFM	VP	E	P to VP	VP
Phillips Cling	YCNM	E	G to VG	P to VP	P
Primrose	YFM	F to G	G to VG	F	VP
Redelberta	YFM	F to G	G to VG	G	VP
Rio Oso Gem	YFM	VG	E	VG	—
Roberta	YFM	F	G to VG	F	F
Rochester	YFM	F to G	G to VG	F	—
Salberta	YFM	F to G	P	G	P
Shipper Late Red	YFM	F to G	G to VG	P to VP	VP
South Haven	YFM	VG	G to VG	VG	F
Summercrest	YFM	P	E	P to VP	—
Sunbeam	YFM	P	E	G	—
Sun-Glo	YFM	VG	G to VG	P to VP	VP
Sunhigh	YFM	VG	E	VG	—
Triogem	YFM	F to G	G to VG	F	—
Valiant	YFM	F to G	—	E	F
Vedette	YFM	F to G	G to VG	F	F
Veteran	YSCM	F to G	E	VG	G
Viceroy	YSCM	VG	E	VG	P
Vivid Globe	YFM	F to G	G to VG	—	—
Wilma	YFM	F to G	P	P to VP	P

*YFM—Yellow freestone, melting flesh; WFM—white freestone, melting flesh; YCSM—yellow cling, semi-melting; YCNM—yellow cling, no melting; YFSM—yellow freestone, semi-melting; YSCM—yellow semi-cling, melting.

**E—excellent; VG—very good; G—good; F—fair ;P—poor; VP—very poor.

these that result in the differences in ratings of a variety for the various purposes.

A considerable number of the varieties make products that rank good or better than good for preservation by all three methods used. These are: Canadian Queen, Early Elberta, Eclipse, Fertile Hale, Globe, Halehaven, Kalamazoo, Massasoit, Rio Oso Gem, South Haven, Sunhigh, and Viceroy. A number of others ranked good or better than good for two of their products and fair to good for the third; among these were Elberta, Fay Elberta, Ideal, Lovell, Lemon Cling, Redelberta and Veteran. Still others were poor for one purpose but good to excellent for the others, as was the case with July Elberta, Kette, Lemon Free, Phillips Cling, Sunbeam, and Sunglow. While a few of these varieties are of rather limited distribution, the majority are important and fairly widely distributed commercial varieties of good to excellent shipping and dessert quality. The fact that they are also potential material for the making of canned, preserved or dehydrated products of high quality gives them additional value over varieties useful only as dessert fruit.

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Potassium Deficiency in a New York Grape Vineyard

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THIS paper reports the diagnosis and partial control of potassium deficiency in a young commercial vineyard situated on a light phase of Dunkirk silt loam in Monroe County, N. Y.

In the summer of 1943, the third growing season following planting, interveinal chlorosis and marginal scorching of leaves, as pictured in Fig. 1, appeared on vines in the central parts of a vigorous 3-acre vineyard near Penfield, N. Y. Of the eight varieties in the vineyard, six showed the symptoms. The two that did not, Concord and Fredonia, were on the extreme south and north sides, respectively. The other varieties, Ontario, Niagara, Brighton, Portland, Caco and Delaware, all showed varying degrees of the symptoms but the vines of all were least affected at the extreme ends of the trellises, which ran east and west. Of the affected varieties, Delaware and Portland were most seriously scorched; by harvest time practically all the leaves on many vines of those two varieties were rolled and shriveled, or had abscissed. Analyses of leaves (see Table I) sampled in late September revealed that potassium percentages were extremely low and calcium and magnesium percentages were extremely high in comparison with the analyses of normal grape leaves reported by Brunstetter (1), and in comparison with analyses of normal leaves from other kinds of fruit plants.[1] Samples of surface soil from the "scorched" area, contained half as much replaceable potassium as surface soil

FIG. 1. Terminal of a cane from a Delaware grape vine, showing potassium deficiency scorch and interveinal chlorosis.

[1]Brunstetter *et al.* (1) reported analyses of leaves sampled on May 9. Potassium (as per cent of dry weight) is at a maximum in young grape leaves and decreases as the season advances (5). Thus part of the difference between the analyses by Brunstetter and those reported here is due to age of leaf.

from the ends of the rows where symptoms were less severe; the former had 0.1 m. e./100 g. soil while the latter had 0.2 m. e./100 g. soil. The potassium analyses of leaves from vines having slight scorch were higher than the analyses of leaves from vines having severe scorch (See Table I).

TABLE I—1943 ANALYSES FROM LEAVES FROM GRAPE VINES AFFECTED WITH SCORCH

Symptom	Leaf Analyses Sep 29, 1943* (Per Cent Dry Weight)		
	K	Ca	Mg
Portland			
Badly scorched	0.25	2.71	0.75
Slightly scorched	0.56	2.29	0.52
Delwaare			
Badly scorched	0.23	1.99	0.70
Slightly scorched	0.61	1.95	0.60

*Analyses by method of Peech (2).

Since the leaf symptom was thought to resemble that of boron deficiency, as reported by Scott (4), a simple test of responses to potassium, boron, and a combination of potassium and boron was made in 1944. Two hundred and forty vines in the area affected the previous year were used for this study. Sixty vines in 20 separate groups of three each received one of the four following treatments:

(a) K—¾ pound 60 per cent K Cl in April and again in June.
(b) Ck—No treatment.
(c) KB—Same K Cl application as in (a) plus 1 ounce of borax in April and again in June.
(d) B—Same borax treatment as in (c) but no K Cl.

Ten of four series of treatments, involving 120 vines, were to Delaware vines, four were to Caco, two were to Portland, and four were to Ontario.

The interveinal chlorosis and marginal scorching of leaves was starting to show up by July 12, 1944, and it had become rather marked on July 26. At the latter date it was evident that the K Cl treatment was beneficial. On August 16, three apparently normal leaves were taken from about median positions on vigorous canes from each vine. The leaves for each group of three vines were com-

TABLE II—LEAF ANALYSIS AND RESPONSE OF GRAPEVINES TO POTASSIUM

Treatment	Leaf Analysis* (Per Cent Dry Weight)	Symptoms** (Number of Groups of Three Vines Showing Scorch)			
		Severe	Moderate	Slight	None
K	.69 ± .031†	0	2	4	14
Check	.36 ± .034	10	6	3	1
K + B	.68 ± .077	0	1	5	14
B	.30 ± .023	5	10	4	1

*Nine leaves per sample taken on August 16, 1944 analyzed by method of Peech and English (2).
**Scoring was done on September 7, 1944.
†Standard error.

posited for a single sample to be analyzed for potassium. On September 7, the vines were scored according to the severity of scorch. Table II summarizes the data on scorch and potassium analysis. Since the response was the same for all four varieties, the table does not differentiate among them. It seems clear from the table that the increase in leaf potassium was associated with the partial recovery from leaf scorch. Potassium in the leaves from the treated vines was still low in comparison with the analyses of Brunstetter *et al.* (1), and it seems reasonable to expect further recovery from scorch with further increases in leaf potassium due to a second year of treatment in 1945. The borax treatments did not seem to make any difference in the responses that were measured.

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Temperature and Maturity in Relation to Raisin Production

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MANY factors are involved in the production of satisfactory raisins. Two important considerations are the required temperatures during fruit development and the maturity of the grapes at the time of harvest for raisin drying. A previous report (1) listed the very limited number of vinifera grape varieties that are used in this country for commercial raisin production. The relationship of the maturity of the fresh grapes to the resulting raisins has been indicated by Jacob (2) for the varieties Sultanina (Thompson Seedless) and Muscat of Alexandria (Muscat). This report gives a summary of temperatures during fruit development and the results of drying six vinifera grape varieties at different sugar percentages and a comparison of the resulting raisins. The varieties included in these tests, in order of ripening, are Corinthe Noir (Zante Currant) Black Monukka, Sultanina, Feher Szagos, Muscat of Alexandria, and Malaga.

METHODS

Samples of fresh fruit of the different varieties were harvested at intervals as the sugar percentages in the fresh fruit increased during the season. Composite samples of the fresh fruit from each lot were taken for sugar and acid determinations. Sugar determinations were made on the fresh juice with the Balling's scale saccharometer. Acid determinations were made on the juice samples by titrating with N/10 NaOH with phenolphthalein as the indicator and calculated as grams of tartaric acid per 100 cc of juice sample. All lots were dried in the sun in the usual commercial manner.

The various lots of raisins were weighed, stemmed, and thoroughly mixed to obtain a representative sample from each lot for moisture, sugar, and acid determinations. The moisture determinations were made with the Dried Fruit Moisture Tester (an electrical method, based on the Wheatstone's Bridge, developed by Mr. C. D. Fisher, of the California Dried Fruit Association). The sugar determinations were obtained by a modified procedure of the Munson-Walker method and calculated as invert sugars. The acid content[1] in the raisin samples was determined by titration. A water suspension of ground raisins was filtered to obtain a clear filtrate and titrated to an end point of pH 8.3 with a known solution of NaOH. The acid content was calculated as tartaric acid. All determinations on the raisins were then adjusted to a standard of 15 per cent moisture in the finished raisins.

DISCUSSION

Within a raisin-producing district certain temperatures are necessary to mature the grapes. At the Fresno Station, temperatures have

[1]Acid determination made by Miss Doris Bahling.

been summarized for the period 1938 to 1944, inclusive, covering the period from full bloom to harvesting date in these various years. These data are given in Table I.

TABLE I—RELATIONSHIP OF TEMPERATURE AND SUGAR PERCENTAGES, 1938 TO 1944

Variety	Blossoming to Ripening (Days)	Sugar Percentages (Balling's)	Day-Degrees Over 50 Degrees F Mean Temperature
Corinthe Noir	85 ± 5.8*	24.8 ± 1.8*	2408.7 ± 439*
Black Monukka	99 ± 5.0	19.3 ± 0.7	2641.4 ± 113
Sultanina	103 ± 4.5	21.6 ± 1.3	2893.7 ± 111
Muscat of Alexandria	119 ± 9.0	22.5 ± 1 5	3294.2 ± 333
Malaga	121 ± 8.0	18.9 ± 2.7	3325.9 ± 299

*S.D. denoting variability only.

Table I indicates the order of ripening of the different varieties and the number of days that elapsed between blossoming and the time of harvest, with the average sugar percentages that had developed, as averaged for the 7-year period. The sugar percentages represent the averages that had developed at the time of harvesting, but do not necessarily represent the maxima possible for the different varieties. While other factors affect sugar development, certain temperatures have been shown to exist between blossoming and ripening. At the Fresno Station the day-degrees above a mean of 50 degrees F were averaged for the 7-year period. Table I shows that an approximate range of 2400 to 3500 day-degrees over 50 degrees F, accumulated during the blossoming to the ripening period for the varieties listed, under the climatic conditions of the Fresno district. The accumulated day-degree temperatures were different for the different varieties. The Corinthe Noir, one of the early raisin varieties, developed 24.8 per cent sugar during an accumulation of 2400 day-degrees over 50 degrees F, whereas the Muscat of Alexandria, a later-maturing variety, developed an average of 22.5 per cent sugar during an accumulation of 3294 day-degrees over 50 degrees F.

Table II gives the relationship of composition of fresh fruit of the various varieties to the resulting raisins. The varieties are listed in order of their ripening. The sugar percentages (Balling's scale), and the acid determinations on the fresh fruit as the harvest progressed are shown, together with the drying ratio, per cent sugar, and acid determinations on the resulting raisins.

The drying ratio of fresh grapes to the resulting raisins tends to decrease as the sugar (Balling's scale) of the fresh fruit increases. Thus, at the higher sugar readings less fresh fruit is required to make one pound of raisins. Averages taken from Table II indicate that about 4.7 pounds of fresh fruit at sugar percentages ranging from 17 to 19 were required to make 1 pound of raisins; and similarly 3.8 pounds of fresh fruit with 20 to 22 per cent of sugar, and 3.5 pounds of fresh fruit with 23 to 25 per cent of sugar. Based on these approximated ratios of drying, for each degree rise in sugar, Balling's scale,

TABLE II—RELATIONSHIP OF COMPOSITION OF FRESH FRUIT TO RESULTING RAISINS AT SUCCESSIVE SAMPLINGS DURING THE SEASON

Fresh Fruit		Raisins (Adjusted to 15 Per Cent Moisture)		
Sugar Balling's Scale	Acid (Tartaric) Grams Per 100 Cc	Fresh Dry Ratio	Sugar Per Cent as Invert	Acid (Tartaric) (Per Cent)
		Corinthe Noir		
18.6	0.86	4.47-1	69.6	3.90
21.4	0.80	3.81-1	69.9	3.24
23.4	0.70	3.60-1	70.7	2.53
25.9	0.67	3.38-1	71.6	2.27
		Black Monukka		
15.8	0.49	5.47-1	70.9*	2.71
16.7	0.43	5.17-1	62.6*	2.27
18.5	0.40	4.51-1	69.6	1.94
21.6	0.36	3.73-1	69.7	1.81
		Sultanina		
18.5	0.76	4.32-1	71.3	3.34
19.0	0.68	3.76-1	73.8	2.99
20.1	0.59	3.73-1	72.3	2.36
23.6	0.45	3.59-1	68.9*	1.71
		Feher Szagos		
18.7	0.71	4.12-1	52.5*	3.34
20.2	0.63	3.70-1	67.5	2.54
21.5	0.53	3.68-1	65.3	2.15
23.0	0.50	3.52-1	68.3	1.71
		Muscat of Alexandria		
15.6	0.79	5.82-1	57.0	4.63
18.0	0.60	4.54-1	64.2	2.06
20.8	0.58	4.10-1	63.6	2.77
24.4	0.50	3.56-1	65.3	1.59
		Malaga		
15.6	0.86	5.06-1	61.5	4.55
17.2	0.75	4.94-1	64.0	4.12
17.7	0.70	4.80-1	68.3	3.36
19.0	0.59	4.10-1	53.8*	2.26

*Data appear inconsistent with other samples.

in the fresh grapes, between 18 and 26 per cent, an additional 23.5 pounds of raisins may be obtained per ton of fresh grapes. This estimate of added production of raisins per ton of fresh grapes does not take into consideration that some additional weight of fresh fruit may also be obtained when the grapes are left on the vines to develop the additional sugar percentages. As suggested by Jacob (2), an estimate of the drying ratio may be approximated by dividing 100 minus the percentage of moisture in the raisins by the sugar (Balling's scale), of the fresh fruit. With a 20 per cent sugar (Balling's scale) reading of the fresh fruit, and a desired 15 per cent moisture content in the raisins, the drying ratio should approximate 85 (100 − 15) divided by 20, or a ratio of 4.25 to 1.

The sugar percentages in the various lots of raisins did not correspond uniformly with the Balling's scale readings in the fresh fruit. Some of the sugar readings in the raisins appear inconsistent with the trend of the other samples and may indicate variations within the sample. In general, fresh grapes with the lower sugar readings

produced raisins of a lower sugar content. The seedless varieties Corinthe Noir, Black Monukka, and Sultanina ranged somewhat higher in sugar content of the resulting raisins than did the varieties Feher Szagos, Muscat of Alexandria, and Malaga, which contain seeds. This may be accounted for partly by the weight of seeds in the seedy types, which enters into the computations in the sugar determinations made on the raisins.

The acid content in the resulting raisins decreased quite uniformly as the maturity of the fresh grapes increased. The acid readings in the resulting raisins appear to be closely related to the acid readings in the fresh fruit multiplied by the drying ratios for the various lots. The acid content of the raisins, as suggested by Jacob (2), appears to offer some possibilities in judging the quality of raisins. The acid content, however, does vary with the different varieties used for raisin purposes. Table II indicates that the acid content of Corinthe Noir raisins was noticeably higher than in either Sultanina or Muscat of Alexandria raisins. The Black Monukka raisins were lower in acid content for similar sugar percentages in the fresh fruit, in comparison with the other types. The Malaga raisins were relatively high in acid, but full maturity of the fresh grapes had not been reached at the time of harvesting for these drying tests.

Summary

The temperature averages in Table I for the 7-year period indicate the day-degrees that elapsed between blossoming and the development of the sugar percentages shown as the average for each of the five vinifera varieties. The averaged number of day-degrees that intervened between blossoming and ripening varies with the variety and indicates the earliness or lateness of the variety in reaching the requisite sugar percentage. In the drying tests, fresh grapes with high sugar percentages not only gave a greater yield of raisins in proportion to the fresh weight of fruit, but also a slightly higher sugar content and a lower acid content in the resulting raisins.

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The Tartrate Content of Maryland-Grown American Grape Varieties

By H. F. Bergman and C. A. Magoon, *U. S. Department of Agriculture, Beltsville, Md.*

An acute shortage of tartaric acid, used by many industries, has resulted from the almost complete curtailment of importations of crude tartars. The United States normally requires 10,000,000 pounds of tartaric acid and 4,000,000 pounds of cream of tartar. The most important and practically the only source from which these materials can be obtained is from winery wastes. About 1,000,000 pounds of pure tartaric acid are made annually in the United States from wine lees and argols obtained from the wine industry as waste materials in the production of grape wine. The remainder is imported chiefly from Spain, Portugal, and other countries bordering on the Mediterranean and from South America.

In spite of the voluminous literature that has resulted from studies of the nature and amounts of acid components of grapes during maturation, very few data on the tartrate content of whole grapes have been found. Alwood *et al.* (1) give the total tartaric acid-tartrate content of a few varieties of American grapes at different stages of maturity. Their results indicate that free tartaric acid entirely disappears in the ripe fruit, especially in varieties with dark-colored juice, but in varieties with light-colored juice the disappearance is not so complete. Since grapes are the best source of tartrate and are grown so extensively, it is important that data on the tartrate content of a greater number of varieties of American grapes be available. The present study was therefore undertaken.

Material and Methods

The samples used for the analysis were taken[1] in 1943 from vines grown at the Plant Industry Station, Beltsville, Maryland. Each variety was harvested and sampled when market-ripe. Duplicate samples of 500 grams each of freshly harvested grape berries were weighed into a quart glass jar, enough distilled water was added to cover, the jars were placed in a water bath, and after coming to a full boil the jars were boiled for ¾ hour to destroy any yeasts and molds. The jars were then sealed and cooled.

Method of Analysis

The procedure used for determination of combined tartaric acid-tartrate was essentially that of The Western Regional Research Laboratory (3), which is based on the characteristic red color developed by the interaction of sodium metavanadate and tartaric acid in dilute aqueous acetic acid solution. The colors were measured by means of a Coleman 10S spectraphotometer at 540 μ. A concentration transmission curve was prepared from readings obtained with pure

[1]These samples were taken and preserved by N. H. Loomis.

tartaric acid over a range of 1 to 5 milligrams of tartaric acid per sample.

In preparing samples for analysis, the liquid was strained off the grapes and the liquid and pulp were weighed separately. Ten milliliters of the liquid was then transferred to a beaker, 2 to 4 milliliters of normal hydrochloric acid was added, and the solution decolorized by boiling 2 to 4 minutes with 0.1 to 0.3 gram of activated carbon (Darco G 60). After cooling, the solution was filtered through a No. 2 Whatman or similar paper and diluted to 100 ml. An aliquot of 5 ml. was taken from this for colorimetric determination. One hundred grams of pulp from which the juice had been strained were transferred to a Waring blendor and thoroughly disintegrated with 250 ml. of water. This mass was transferred to a flask, 25 ml. of concentrated hydrochloric acid was added, and the mixture was boiled 10 minutes. It was then filtered and washed several times with distilled water to obtain the final volume of 500 ml. A 50-ml. aliquot was then decolorized and neutralized, and the volume made up to 100 ml. A 5-ml. aliquot was taken from this for colorimetric determination. From these determinations the percentage of tartrate in the 500-gram sample was calculated. The results of the analysis are shown in Table I.

TABLE I—THE AVERAGE TARTRATE CONTENT OF DUPLICATE SAMPLES OF AMERICAN VARIETIES GROWN AT THE PLANT INDUSTRY STATION, BELTSVILLE, MARYLAND, 1943

Variety	Percentage of Tartrate Calculated as Tartaric Acid in 500 Grams Fresh Weight			Variety	Percentage of Tartrate Calculated as Tartaric Acid in 500 Grams Fresh Weight		
	In Liquid	In Pulp	Total		In Liquid	In Pulp	Total
Arkansaw	0.88	0.30	1.18	Hartford	0.94	0.16	1.10
Barry	0.74	0.22	0.96	Herbert	0.84	0.16	1.00
Beta No. 3	0.76	0.46	1.22	Kentucky	0.98	0.28	1.26
Bride	0.56	0.42	0.98	Krause	0.86	0.14	1.00
Brighton	0.76	0.22	0.98	Leverkuhn	1.22	0.26	1.48
Brockton	0.80	0.20	1.00	Lindley	0.96	0.24	1.20
Caco	0.74	0.20	0.94	Lucile	0.84	0.20	1.04
Campbell	0.74	0.20	0.94	Lutie	0.80	0.26	1.06
Captivator	0.88	0.22	1.10	Montefiori	0.80	0.28	1.08
Champion	0.72	0.20	0.92	Moore	0.48	0.22	0.70
Chicago	0.88	0.32	1.20	Manito	0.88	0.20	1.08
Cloeta	0.66	0.20	0.86	Niagara	0.76	0.20	0.96
Cochee	0.80	0.32	1.12	Nitodal	0.90	0.18	1.08
Creveling	1.04	0.36	1.40	Peabody	0.84	0.14	0.98
Dakota	1.04	0.24	1.28	Ripley	0.70	0.18	0.88
Diamond	0.88	0.20	1.08	Rockwood	1.00	0.24	1.24
Dracut Amber	0.90	0.40	1.30	Seneca	0.62	0.14	0.76
Early Concord	0.90	0.20	1.10	Studley	0.72	0.18	0.90
Eaton	0.76	0.20	0.96	Sunrise	1.06	0.16	1.22
Elvibach	0.94	0.34	1.28	Watkins	0.80	0.20	1.00
Emerald	0.96	0.20	1.16	Wetkuma	0.54	0.14	0.68
Fredonia	0.98	0.18	1.16	Wilder	0.76	0.18	0.94
Goff	0.88	0.20	1.08	Wittel No. 42	0.68	0.20	0.88
Golden Muscat	0.80	0.12	0.92	Worden	0.80	0.20	1.00
Green Early	0.84	0.20	1.04				

The tartrate content of Maryland-grown American grape varieties was found to be as great as, and in some varieties considerably greater than, that of California-grown varieties of *Vitis vinifera*, which, according to a recent paper by Marsh (2), vary from 0.8 to 1.2 per cent of tartrate as potassium bitartrate. Some additional data on the tar-

trate content of certain California-grown varieties of *V. vinifera* have recently been received. The analyses[2] were made by the metavanadate method during the crushing season of 1943 from grapes grown in the vicinity of Lodi, Calif. The acid contents (Table II) are less than those of grapes grown in some other California areas.

TABLE II—THE TARTRATE CONTENT OF CERTAIN CALIFORNIA-GROWN VARIETIES, 1943

Variety	Per Cent Tartrate	Date
Carignane	0.69	Sep 29
Carignane	0.76	Nov 3
Tokay	0.45	Sep 29
Zinfandel	0.69	Sep 29
Zinfandel	0.67	Nov 3
Alicante Bouschet	0.57	Sep 29

The highest tartrate content in Maryland-grown grapes was found in the variety Leverkuhn, with 1.4–1.5 per cent; the varieties Creveling, Dakota, Dracut Amber, Elvibach, and Kentucky also were high, with a tartrate content only slightly less than that of Leverkuhn. The varieties Moore, New York, Seneca, and Wetumka were found to have the lowest tartrate content of the varieties studied.

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[2]Credit is due to Carl Hendel of the Western Regional Research Laboratory, Albany, Calif., for the analyses, and to the Bear Creek Vineyard Association, Lodi, Calif., for the material.

Effect of Zinc on Yield and Cluster Weight in Muscat Grapes

By WM. B. HEWITT and H. E. JACOB,[1] *University of California, Davis, Calif.*

SHELLING ("coulure"), or dropping of the berries from the clusters soon after bloom, and the formation of small, seedless "shot berries" instead of the normal-sized, seeded berries have always been problems with some European and American varieties of grapes. Many references on the subject indicate that the problems are complex and probably involve several factors, such as climate, soil, pollination, and vine nutrition. Of the European varieties, the Muscat of Alexandria has been consistently referred to as being affected with shelling, and it is one of the most severely affected in California. Winkler (6) has shown marked improvement in set of berries and increased crops of this variety with altered pruning (from short spurs to long spurs or short canes) coupled with crop regulation by flower-cluster thinning. The treatment improved pollen germination and general nutrition of the vine. The responses were correlated with increased carbohydrate supply attributed to greater leaf surface and varied with the locality, indicating that others factors may also have influenced the results.

Shelling of berries from the clusters shortly after bloom and the development of shot berries are common symptoms of the little-leaf disease, which in most varieties is also associated with small, chlorotic, and deformed leaves. Most Muscat vines in the state commonly show varying degrees of shelling even on excellent soils, but rarely show prominent leaf symptoms even when grown on soils that produce severe little-leaf symptoms in other varieties.

Chandler, *et al.*, (1, 2, and 3) reported recovery from little-leaf and increased set of normal berries in the Alicante Bouschet and Carignane varieties after treatment with zinc. One method of applying zinc to the vines was to brush the pruning wounds immediately after pruning, in the dormant season, with a solution of 2 pounds of zinc sulfate in 1 gallon of water. Other methods of applying zinc to vines and trees were also described. These authors also observed that certain fruit trees in the San Joaquin Valley responded to zinc applications even though little-leaf symptoms were not prominent (3). Their reports of little-leaf control led to numerous trials of the zinc sulfate treatment for various troubles of grapevines in many parts of the state, and the problem of shelling in the Muscat of Alexandria received particular attention. The results obtained by growers from these uncontrolled trials were inconsistent, ranging from no benefit to 300 per cent increase in crop. It, therefore, seemed advisable to obtain more detailed information concerning vine responses to zinc, particularly in the Muscat variety.

In evaluating the results from the following experiments, compari-

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[1]The authors wish to express their appreciation to Mr. John L. Quail, Assistant Farm Adviser, Fresno County, and to Mr. A. D. Rizzi, Assistant Farm Adviser, Tulare County, for their assistance in the experiments reported in this paper.

sons have been made by analysis of variance (4), and only odds of 99:1 or greater are claimed significant.

In January, 1938, plots were established in 10 separate vineyards in Fresno and Tulare counties of California involving different soils and cultural practices. Each plot consisted of 150 vines; 50 received no zinc treatment; 50 were treated by brushing the wounds, within a few minutes after pruning in January, with a solution of 2 pounds zinc sulfate in 1 gallon of water; and 50 vines received a foliage spray, 10 to 14 days before bloom, consisting of a suspension of 25 pounds zinc oxide in 100 gallons of water. The zinc oxide spray was used because peaches and certain other crops had shown response to the spray.

In May when the plots were examined, considerable injury to the end bud of the spurs was observed on the zinc sulfate-treated vines. The amount of injury in the different vineyards varied greatly, as did also that among individual vines on the same property. Harvest records from the plots seemed impractical to get; as a substitute, samples of 25 clusters were taken, one from every other vine in each treatment. Each cluster was chosen to represent as nearly as possible the average cluster on each vine. Comparisons of the treatments on the basis of these samples are presented in Fig. 1.

There were marked differences in the average weights of clusters between the zinc sulfate-treated vines and the check vines in 6 out of 10 vineyard plots. Further analysis of the samples, as illustrated in Fig. 1, showed that the response was apparently due to an increase in the number of seeded berries along with a decrease in the number of seedless berries per cluster. The weights of seeded and seedless berries indicated that the treatments had little effect on berry size.

None of the average cluster weights of the zinc oxide-sprayed vines were significantly greater than those from the check vines.

In 1939 plots were established in three of the vineyards used in 1938, number 3, 5, and 7 of Fig. 1. In each vineyard the vines treated with zinc sulfate in 1938 were divided into two lots, 25 of them received no further special treatment, and the other 25 were again pruned in January and treated with zinc sulfate solution as previously described. Also in each vineyard 25 vines not previously used were pruned in January and treated immediately with zinc sulfate, a second lot of 25 vines was pruned and treated in February, and a third lot in March. Two lots of check vines were pruned, one in January and the other in March.

Crop weights were obtained for each lot of vines and an average sample cluster from each vine. A summary of the yield records is shown in Table I. The records show that the yields from the zinc sulfate-treated vines was slightly greater than from corresponding check vines, but the differences were not significant even at the 5 per cent level. Analysis of the data obtained on the average-cluster samples showed no significant differences in respect to average weight of cluster, berry size, and percentage of shot berries.

Very little injury to buds was observed in the 1939 treatments in contrast with the considerable injury observed in 1938. These obser-

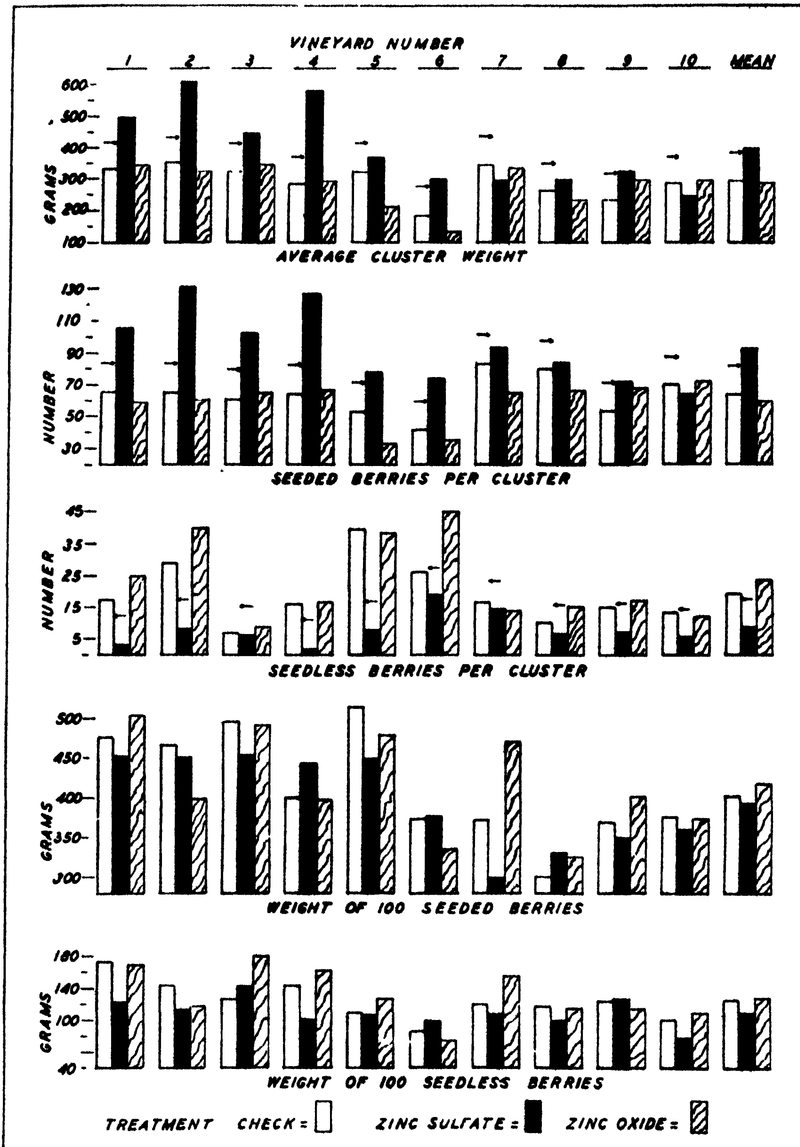

FIG. 1. A comparison between the average of cluster samples taken in 1938 from check, zinc sulfate-treated, and zinc oxide-sprayed Muscat vines in 10 different vineyards of Fresno and Tulare counties. The arrows indicate the level for significance between treatments at 99 : 1 odds.

vations, together with the small benefits obtained in 1939 as compared with 1938, suggest that there may be some relationship between bud injury and fruiting responses with the zinc sulfate treatment.

TABLE I—SUMMARY OF THE 1939 CROP RECORDS FROM EXPERIMENTAL PLOTS OF MUSCAT GRAPES AS INFLUENCED BY TREATMENT* AND THE TIME OF TREATMENT WITH ZINC SULFATE

Vineyard	Crop Per Vine (Kilograms)						
	Treated 1938 Only	Treated 1938 and 1939	Check†	Month Treated, 1939			Check‡
				Jan	Feb	Mar	
3	15.0	16.6	15.8	23.1	16.6	13.4	13.4
5	15.4	20.4	11.4	15.4	20.4	22.3	17.7
7	11.6	12.3	14.5	14.5	16.0	17.4	12.4
Mean	13.0	16.4	13.9	17.7	17.7	17.7	14.5

*Zinc sulfate solution, 2 pounds per gallon of water, was brushed on the pruning wounds within a few minutes after pruning.
†This same group of vines was used as a check lot in 1938 and again in 1939.
‡This lot of vines was used in 1939 only.

Muscat vines at Davis, also subject to severe shelling, were treated in January, February, and March with zinc sulfate solution. No consistent differences existed between treated and untreated vines either in harvest weights or cluster samples.

Trials of the zinc sulfate treatment were made again in 1940 in vineyards 3, 5, and 6 as numbered in Fig. 1. A similarly replicated series of Muscat vines was treated at Davis. Separate lots of vines in each vineyard were treated in December, January, and February. Each treatment of 25 vines was compared in three replications in randomized blocks. Very little injury to spurs was observed in any of the treatments. Just before harvest, sample average-clusters were taken from each vine. Yield records were obtained. A comparison of the data collected from plots in vineyards 3, 5, and 6 is shown in Fig. 2.

Differences attributable to the time of treatment — December, January, or February — were not consistent; a significant difference in this respect existed only in vineyard 5 in favor of the February treatment. The vines treated with zinc sulfate during December and January in vineyard 3, all of the zinc-treated vines in vineyard 5, and only those treated during December in vineyard 6, yielded significantly larger crops than the corresponding check vines.

A comparison of the treatments on the basis of cluster samples differed slightly from that on the basis of total yield. The data on average weight of cluster show that the average-cluster sample, as collected, tended to give an exaggerated impression of the effect of treatment on total yield. However, it further shows that yield figures alone do not tell the complete story, in that the average cluster of the zinc-treated vines was better than the average cluster of the nontreated vines. No counts were made of the number of clusters on each vine. The average cluster weights of zinc sulfate-treated vines were significantly greater than those of the check vines in all plots, except the February treatment in vineyard 6 (Fig. 2). The graphs further show that differences in cluster weights were due to increases in number of seeded berries.

No differences existed between zinc sulfate-treated and nontreated vines in the series located at Davis.

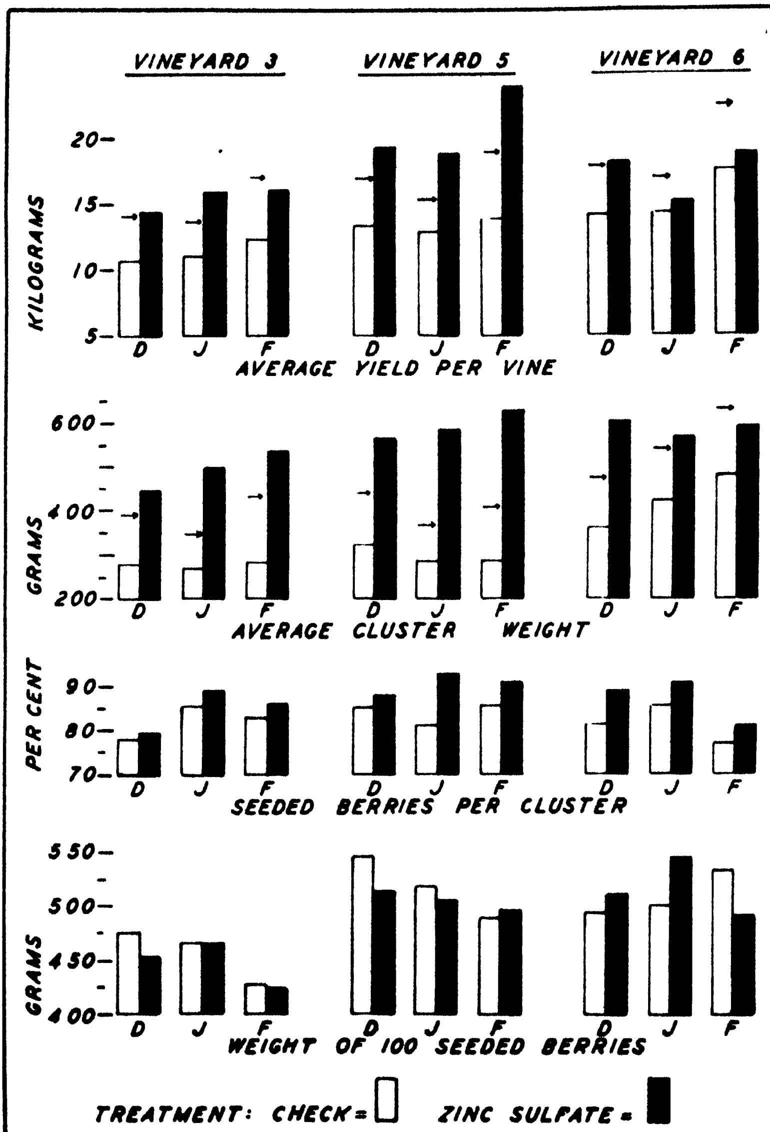

FIG. 2. A comparison of total yields and of representative cluster samples taken from check and zinc sulfate-treated Muscat vines in three different vineyards of Fresno County for the 1940 season. The arrows indicate the level for significance, between each pair of check and zinc sulfate treatments, at odds of 99:1. D = treated in December, 1939; J = treated in January, 1940; and F = treated in February, 1940.

At our suggestion, a grower near Delano in Kern County treated his Muscat vineyard for several years by brushing the pruning wounds with zinc sulfate solution. The yield records of his vineyard are shown in Table II. In 1937 and 1938 the treatment increased the crop by about 60 per cent. In 1939 the grower treated all vines; hence no comparison could be made. The average yield per vine in 1939 dropped below the 1937 and 1938 figures, but it was greater than that for 1936.

TABLE II—ANNUAL YIELDS OF RAISINS FROM MUSCAT VINES IN A KERN COUNTY VINEYARD TREATED WITH ZINC SULFATE AS COMPARED WITH YIELDS FROM UNTREATED VINES

Year	Number of Vines		Total Yield in Trays* of Raisins		Trays* of Raisins Per Vine	
	Treated	Check	Treated	Check	Treated	Check
1936	——	3,975	——	3,934	——	0.99
1937	2,067	1,908	3,950	2,198	1.91	1.15
1938	3,817	158	7,520	190	1.97	1.20
1939	3,975	——	5,534	——	1.39	——

*Drying trays, 2 × 3 feet, which hold about 10 kilograms of fresh grapes.

DISCUSSION

The variable responses of Muscat vines to the application of zinc sulfate solution indicate that shelling and the development of shot berries in this variety is a complex problem not solely related to zinc. In some vineyards a partial to nearly complete correction was obtained by the application of zinc to the vines, in other vineyards the zinc treatment apparently had no measurable effect on shelling. The degree of response seems to vary with the season.

In all of the tests, the most consistent response obtained from pruning-wound painting with zinc sulfate solution was the increased number of normal seeded berries per cluster. This improved the set of fruit and in turn resulted in heavier clusters and larger crops. The size of the berries, both seeded and seedless, was influenced but little if at all (Figs 1 and 2). The number of seedless (shot) berries per cluster was decreased slightly by the treatment in 1938, but the difference was significant, at the 1 per cent level, in only 6 of the 10 plots (Fig. 1). The time of ripening of the fruit was not advanced by the treatment, but it was sometimes delayed where the crop was markedly increased.

Experiments reported in this paper, that of Snyder (5) and records from commercial applications of the zinc treatment, show that some vineyards respond every season to zinc, and that in these treated vineyards vines consistently produce better crops than do nontreated vines. However, Muscat vines in other vineyards in the same districts and in other districts, although severely affected with shelling, do not respond to the zinc sulfate treatment; vines in these vineyards do, according to Winkler (6), respond favorably when the leaf surface has been increased by altered pruning and crop regulated by flower-cluster thinning. Climatic influences were not investigated.

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Fasciation in Horticultural Plants With Special Reference to the Tomato

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FASCIATIONS are of interest to horticultural workers because of the part they play in production of economic plants. In general, fasciations are characterized by an increase in weight and volume of plant tissue, and by lack of organized regularity in growth as contrasted with the normal individuals of the same variety or species (8, 11, 12). All types of plant structures are affected, including the leaves, stems, fruits and roots. Observations on tomatoes reveal that the main stem axis and all floral parts may be intensely modified. The apex of the stem becomes distorted, flattened and disorganized. As many as 215 locules have been observed in a single fasciated fruit of the variety Beefsteak. Such monstrous fruits when mature may contain up to 250 seeds, as contrasted with approximately 40 seeds in the normal two-loculed fruits of Red Currant. The peduncle in these fasciated forms may have as many as 120 vascular bundles, while the normal types such as Red Currant possess five. Abnormalities like those indicated above are characteristic of the divergence of fasciated organs from the orthodox type.

A study of certain aspects of the genetic basis of fasciation in the tomato has recently been initiated at this Station. Since one of the most striking affects of fasciation in this plant is the increase in number of locules in the fruit, particular attention is being given to observations on this character. This will provide a body of objective numerical data supplementary to those which will be obtained from observations on the more general morphological effects of fasciation.

Although fasciations have frequently enhanced the value of certain varieties, they may, under certain conditions, cause serious losses. Not infrequently a high percentage of tomato flowers in a greenhouse become fasciated. This appears to be especially true with certain varieties, particularly when low temperatures and high nitrogen soil levels exist in the forcing house. Such fasciated flowers seldom set fruit but occasionally set large, irregular, and convoluted specimens. Evidently fasciations may sometimes be determined by environmental or external factors, as well as by hereditary or internal factors. One of the most familiar of the hereditary types of fasciation is that of the cockscomb, *Celosia argentea* var. *cristata.* This variety is valued because of its extremely fasciated inflorescence. Small fruit growers commonly find fasciated fruits among strawberry varieties; flattened fruits the size of the palm of the hand have been observed on several occasions, and the largest fruits are frequently the most fasciated. Certain varieties appear to produce fasciated fruits quite regularly

[1]The author wishes to express special thanks to Dr. Orland E. White, Director of The Blandy Experimental Farm, and to Dr. Ronald Silow, Visiting Professor of Plant Breeding, for their many suggestions and guidance. The author also wishes to acknowledge the aid given by the General Education Board in providing a fellowship grant.

as, for example, Fairfax, Marshall and Sharpler, while others seldom do. Thus Darrow (2) noted many fasciated fruits, stems and inflorescences in the Fairfax strawberry grown in the Southern States. The degree of fasciation varied from one locality to another. The author has frequently observed strikingly fasciated fruits in the varieties Marshall and Sharpler. The pedicel, calyx and fruit are irregular, and often distinctly flattened and digitate. Here receptaclar tissue is primarily involved. The abnormal morphology of these strawberry varieties appears to be influenced by environmental as well as genetic conditions. Examples of strictly hereditary fasciation, where the character is regularly transmitted to the offspring, occur in tomato, oenotheras, peas, tobacco, corn, cockscomb and perhaps in peaches. On the other hand, fasciations which apparently result primarily from environmental conditions occur in tomato, oenotheras and peas, as well as in the pumpkins, sweet potatoes, buttercups, petunias, *Echeveria*, etc. These are indistinguishable from the hereditary types when they occur in the same species or variety. Fasciated plants originate either through gene mutations or as the result of environmental effects such as pressure, mutilations by insects, frosts, or they are associated with marked fluctuations in nutrient and water supply.

Papers dealing with fasciation from an experimental standpoint in both its environmental and genetic aspects have been published by De Vries (3), Hus (5), White (12), Powers (8), and others. White (11, 12) has reviewed this literature up to 1913. It is interesting to note that Mendel investigated the inheritance of fasciation in garden peas and found it to differ from the normal type by one recessive gene. This work has been repeated and confirmed by many other investigators. Shull (9) has observed that fasciation in oenotheras is also determined by a single gene.

There is abundant evidence that both genetic and environmental factors operate in the induction of fasciation in the tomato. In this crop, the genic nature of multilocular fruits, as expressed in such varieties as Ponderosa and Johannisfeuer, has been demonstrated by many workers, including MacArthur (7), Powers (8), and Yeager (13); by linkage studies, two of the gene loci concerned have been located on particular chromosomes. Some other workers have dealt more with the cultural aspects of fasciation in the tomato. In the Globe tomato, Howlett (4) observed that the most extremely malformed and fasciated flowers occur in the early spring greenhouse crop. He associated this abnormality with the very high nitrogen and low light conditions of this season. He stated that disturbed growth was influenced in all varieties by environmental conditions. He found that low temperatures, from 45 to 55 degrees F in the vegetative phase, will increase such fasciation and asserted that high nitrogen will do the same, particularly at low temperatures.

Watts (10) states that irregularity in tomato fruit shape does not result from faulty pollination, since it is as frequent in fruits which resulted from hand pollination as in those which resulted from autonomous pollination. He recorded that irregularity in pistil shape was evident early in the development of the buds in plants grown at low

temperatures. This condition was not found at higher temperatures. Nitrogen seemed to make no difference in fruit shape. He recorded that irregularity in pistil shape was evident early in the development of a large number of buds in the first clusters of plants grown at low temperatures. Affected blossoms had pistils which were thick and distinctly fasciated, and failed to set fruit. Other floral parts were also malformed, and pollen seemed to have been arrested in its development after the reduction division occurred.

Crist (1) showed that "cripples", as he called these fasciated fruits, do not necessarily result from any recognizable relation of carbohydrates and nitrogen, but from a type of growth following a "hardened" condition, or associated with relatively low temperatures. This suggests a cause similar to that which Hus (5) had observed very much earlier. He concluded that optimum growth conditions associated with sudden checks were highly favorable to the induction of fasciations. These could also result from injuries to the growing point by insects. Hus induced fasciation by special techniques in a number of species belonging to several families; in other species the same techniques were without effect.

The present preliminary investigation was designed (a) to establish the extent of fasciation occurring in commercial varieties by measuring locule number, (b) to observe whether or not segregation was occurring among individuals of the population of a commercial variety, and (c) to measure the effect of seasonal influence on the degree of fasciation.

Seeds of 30 varieties were sown in flats in a greenhouse during March, 1944, at The Blandy Experimental Farm. Plants were transplanted to a relatively uniform field during the second week in May. Observations were made during each of the months of July, August and September. Growing conditions during this period were especially dry, and thus the fullest expression of fasciation genes may not have been obtained. However, environmental conditions were similar for all varieties involved. The varieties studied, the majority of which are commercial varieties, exhibited a wide range in mean locule number, from two to as many as 14 or 16 (Table I). The mean

TABLE I—AVERAGE LOCULE NUMBER PER FRUIT IN 30 TOMATO VARIETIES

Variety	Average Locule Number			Variety	Average Locule Number		
	Jul	Aug	Sep		Jul	Aug	Sep
1. Red Currant	2.05	2.04	2 01	16. Earliest and Best	6.84	5.77	4.41
2. Red Pear	2.04	2.02	2.02	17. Pritchard	5 94	5.87	5.41
3. Italian Canner	2.05	2 05	2.00	18. Orange King	6.65	6 69	5.80
4. Red Plum	2.14	2.12	2.06	19. Matchless	8.75	7.77	6.48
5. Sugar	2.32	2.27	2.05	20. Break O'Day	8.48	8.07	6 50
6. Yellow Pear	2.38	2.32	2.10	21. Bison	9.71	9.63	7.61
7. Baldwin II	2.39	2.36	2.08	22. Prodigious	10.86	10.29	9.02
8. Red Peach	2.85	2.86	2.37	23. White Beauty	10.97	10.87	8.71
9. Yellow Peach	3.10	3.10	2.77	24. Oxheart	11.12	11.88	9.28
10. Truckers Delight	4.12	3.96	3.47	25. Ponderosa	12.12	11.80	10.31
11. Summerset	4.51	4.73	3.72	26. Beefsteak	13.49	11.99	9.75
12. Stokesdale	4.97	4.80	3.83	27. Triple L Crop	14.59	12.78	9.95
13. Marglobe	5.38	4.91	4.14	28. Brimmer	14.07	14.57	10.34
14. Golden Queen	5.98	5.85	4.92	29. Colossal	15.48	14.48	10.88
15. Rutgers	6.02	5.75	5.07	30. Stone	15.45	16 06	9.73

monthly values cited are based on observations on ten flowers on each of ten plants. There was a striking trend toward lower locule number as the season advanced. This was exhibited in every one of the varieties grown; even in the case of the three varieties (Oxheart, Brimmer and Stone) in which readings for August were slightly higher than those for July, there was a very marked decrease in locule number in September. Analysis of variance indicated that the differences in mean locule number between months within a variety, as were those between varieties, were highly significant. The end-of-season effect was most pronounced in the highly fasciated varieties; this was clearly brought out by a highly significant interaction between varieties and months.

A preliminary examination of the data gave no evidence of segregation for locule number between plants within a variety. Analyses of variance were calculated for three of the more highly fasciated varieties, in which segregation might be expected to be more easily detected than in low locule-number varieties.

TABLE II—SUMMARIZED FREQUENCY DISTRIBUTION OF LOCULE NUMBERS ON TEN PLANTS IN EACH OF THREE HIGHLY FASCIATED VARIETIES

Month	Locule Number																												Mean
	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30 39	
												Variety 1 — Break O' Day																	
Jul	—	1	9	12	16	13	16	17	8	3	1	1	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	8.48
Aug	1	1	6	19	27	14	10	7	5	3	—	3	2	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	8.07
Sep	—	8	28	27	18	8	5	2	—	—	—	2	1	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	6.50
												Variety 2—Triple-L-Crop																	
Jul	—	—	—	—	—	3	3	4	14	17	10	11	5	7	10	3	2	3	2	1	—	—	—	1	—	1	2	39-1	14.57
Aug	—	—	—	1	11	3	9	4	16	10	9	7	5	7	6	1	2	2	5	1	—	—	—	—	1	—	—	—	12.78
Sep	—	—	1	10	15	14	10	18	5	7	4	4	5	3	2	1	1	—	—	—	—	—	—	—	—	—	—	—	9.92
												Variety 3—Colossal																	
Jul	—	—	—	—	—	3	3	6	10	7	7	6	8	14	8	6	6	3	5	2	1	—	2	1	—	—	2	—	15.48
Aug	—	—	—	1	3	9	9	5	14	7	10	5	9	8	7	—	2	2	1	3	1	2	—	—	—	—	1	—	14.48
Sep	—	1	3	5	4	15	19	5	13	9	3	4	3	9	2	2	—	1	1	—	—	1	—	—	—	—	—	—	10.88

Extract from Analyses of Variance

	Sum of Squares	Degrees of Freedom	Variance	Variance Ratio	P
		Variety 1—Break O' Day			
Plants	98.8	9	10.9	1.48	>0.05
Months	218.5	2	109.2	14.80	Very Small
Error	133.2	18	7.4	——	——
		Variety 2—Triple-L-Crop			
Plants	181.8	9	20.2	1.66	>0.05
Months	1095.2	2	547.6	44.90	Very Small
Error	219.4	18	12.2	——	——
		Variety 3—Colossal			
Plant	419.2	9	46.6	2.16	>0.05
Months	1170.7	2	585.4	27.10	Very Small
Error	388.9	18	21.6	——	——

There were no significant differences between plants within these three high locule-number varieties. Within the limitations imposed by the restriction of observations to ten plants in each variety, it may therefore be concluded that each of the horticultural varieties included

in this study is characterized by a fairly uniform genotype in respect to the fasciation character. In striking contrast, however, is the very highly significant differences between months. It is evident that in the study of the inheritance of fasciation the influence of the environment cannot be neglected.

Discussion

Cultivated tomatoes exhibit a wide range in locule number. Some are characterized by as few as two locules, which number is typical of the genus as a whole, while at the other extreme as many as 215 locules have been observed in a single flower. Those forms with a high locule number are usually described as fasciated, especially if the high number is associated with irregularity of outline of the fruit. The term has been used to describe a series of phenomena, the most striking feature of which is regions of uncontrolled or unregulated and disorganized tissue growth, which results in an increase in weight and volume of plant tissue. Fasciations may be localized in a particular organ, or an entire plant may be affected. In tomatoes, many of the cultivated varieties consistently produce fasciated fruits. The only parts of the plant usually affected are the flowers, involving stamens, corolla and calyx, as well as the pistil, and there are frequently considerable differences in expression of fasciation between fruits on a single plant. Occasionally stem fasciations of several types occur in the tomato, and these may or may not be associated with fasciation in the fruits.

The fasciation character differs from many mono-genic expressions in its sensitivity to environmental factors. Investigations (2, 5, 6, 10, 11,) have clearly demonstrated that many different causes may produce fasciation. Such environmental factors as sudden cold shocks, mutilations, prolonged drought followed by abundant moisture, insect bites, and low temperatures combined with high nitrogen levels in the soil and low photosynthetic activity are responsible for many fasciations.

In most commercial varieties of tomatoes it is apparent that the fasciation expressed in the blossom, fruit, and peduncle is primarily genetic in origin. Since the tomato is normally almost entirely self-pollinated, there is a high probability that most varieties will be relatively homozygous in genotype, in which case selection for smooth-fruited types within a variety is likely to be of limited effectiveness. However, Lesley and Rosa (6) have published work dealing with selection for smoothness in the variety Santa Clara Canner. They have successfully isolated, by single plant selection, a number of lines which differ from the parental variety in shape and size of fruit, season of maturity, and other characteristics such as roughness at the stylar and stem ends. They concluded that Santa Clara Canner is a highly heterozygous variety. This varietal condition in Santa Clara Canner apparently is atypical for most commercial sorts, as shown by the uniformity of the varieties in this present study.

Effects of environment, super-imposed upon the genetic basis, may modify the expression of the fasciation character to a greater or lesser

degree depending upon the genotype of the variety considered. It is seldom possible to distinguish environmental and genetic fasciations by simple inspection. The two, however, may be easily separated by testing progenies from known crosses, or by controlling the active environmental factors. The environmental influence may be simple in nature, or many complementary factors may be playing on the plant. However, with gene-caused fasciations, no alteration of the environment has been found that will eliminate the expression of this character. Quantitative modification may occur, but the seed will continue to reproduce the fasciation generation after generation.

In conclusion, it may be pointed out that significant differences in locule number between varieties have been established. These must have a genetic basis. However, this preliminary study has also demonstrated the important influence of environmental factors on the expression of fasciation. In the commercial varieties studied, it appears that the fasciation gene or genes are present in a fairly homozygous condition; thus selection should not prove a valuable tool in eliminating irregular corrugated fruits within such varieties. The most promising program for producing smooth-fruited tomato varieties appears to be one of selection within the F_2 progenies of known crosses and the selection of infrequent chance mutations.

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Experimental Production of Hybrid Tomato Seed

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SINCE increase in yield of tomatoes due to heterosis, has been observed and reported by a number of investigators, the production of hybrid tomato seed would seem to be of considerable importance if the seed can be produced at a reasonable cost. Among the earlier workers who have reported hybrid vigor in tomatoes are Ashby (1), Larson (8), Luckwill (10), Powers (12), and others. That tomato hybrids can be profitably grown commercially has been indicated by Barrons (2), Barrons and Lucas (3), Burgess (4), Driver (5), Hadfield and Calder (6), Hayes and Jones (7), Larson and Currence (9), Meyer and Peacock (11), Powers (12), Powers and Lyon (13), and Wellington (16, 17). Powers' work (unpublished) and unpublished data collected by the authors indicate that F_1 hybrids may be of commercial importance for the Central Great Plains region where early yields are essential.

In recent work reported by Barrons and Lucas (3) information was given on the technique and cost of hybrid tomato seed production in Michigan. Studies on techniques and pollination cost in hybrid tomato seed production, made in connection with breeding work for earliness conducted at the Cheyenne Horticultural Field Station, Cheyenne, Wyoming, have indicated that the hybrid seed can be produced at a reasonable cost. Because of the present emergency and the demand for increased food production it seems desirable to present these data now and describe the techniques used to obtain them.

MATERIALS AND METHODS

The plants used in the experiments reported here were from breeding material produced at the Station and were grown in the greenhouses and in the field during the summers of 1943 and 1944. To facilitate the work, all plants were staked, and pruned to two or three stems in the case of the determinate type vines in the greenhouses. The flower clusters to be pollinated were tagged and any flower that had passed beyond the proper stage for emasculation was picked off.

To study the effects of environmental conditions on fruit set with hand-pollination, ten plants were grown under each of the following conditions in 1943: (a) in the greenhouse, (b) in the field under cages covered with two thicknesses of cheesecloth, and (c) unshaded in the field. The checks, ten open-pollinated, unpruned plants of the same parentage, were grown in the field, adjacent to the treated plants.

In 1944, two treatments were used to study pollination time in relation to fruit set and seed yield in the field. One treatment was to emasculate and pollinate all flowers in a cluster; in the second treatment only four flowers per cluster were emasculated and pollinated. As it was found that there was no significant difference in time involved and per cent of fruit set between the pollination of four flowers

in a cluster and the pollination of all flowers, the results were combined when summarized in Table II. Check plots were included which consisted of open-pollinated, unpruned plants. There were twelve plants per plot and three plots for each treatment, the parentage of the plants being the same as in 1943. In the greenhouse ten hand-pollinated plants were used as well as ten open-pollinated check plants.

The flowers were emasculated before the petals had become fully open. Normally the anthers would have dehisced 1 or 2 days later. Anther collars were removed with a pair of straight forceps which had one point sharpened. The sharpened point of the forceps was thrust into the anther tube near the base and a segment of the tube torn out. The procedure was completed by grasping the remaining portion of the tube and pulling it away from the ovary. Care was used to avoid breaking the style at the base or puncturing the ovary. When this method is used, the flowers can be emasculated rather rapidly and with very little injury.

The pollen was gathered on a glass slide by vibrating the fully matured flowers with an electric vibrator (see Fig. 1). By so doing, an abundance of pollen was secured and the flowers of the male parent were selfed at the same time. Thus the perpetuation of the pollen plant was assured without growing extra plants of the pollen

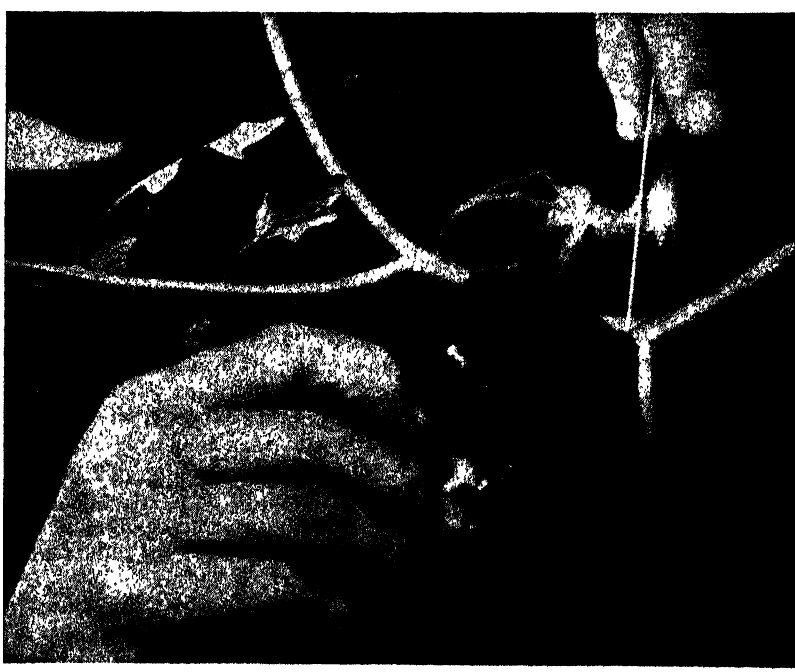

Fig. 1. Collecting pollen on a glass slide by vibrating the flower with an electric vibrator. The blurring near the flower indicates the vibrator tongue in motion.

line. The type of vibrator used by the authors is similar to that made by Osgood (18).

The flowers were pollinated immediately after emasculation. The method of pollinating with pollen collected on a glass slide, also known as the spoon or watch glass method, has been described by Voorhees (15). Pollinating by this technique is much more rapid than the "knife" method used by Barrons and Lucas (3).

RESULTS 1943

The chi-square computations for fruit set show homogeneity within a given treatment for clusters of three to seven hand-pollinated flowers for the following treatments: in the greenhouses, shaded in the field, and unshaded in the field; and for clusters of three to seven open-pollinated flowers of the check plants in the field. The mean set for the 3- to 7-flowered clusters of the unshaded plants in the field was 61.9 per cent as compared with a mean set of 62.1 per cent for the open-pollinated check plants in the field (Table I). Shading the plants in the field resulted in an increase over non-shaded plants of 7.5 in percentage of set. This was highly significant. Barrons and Lucas (3) obtained an 8 per cent increase of fruit set by shading under their conditions. A mean set of 77.4 per cent was obtained for cross-pollinated flowers in the greenhouse.

In addition to having the highest percentage of flowers set, the greenhouse plants had the lowest number of fruits per ounce of seed, or the highest seed yield per fruit (Table II). There was considerable difference between the seed yields of the shaded and unshaded plants in the field. Although the percentage of flowers set on the hand-pollinated, unshaded plants in the field did not differ significantly from the per cent set on naturally pollinated checks, the seed yield per hand-pollinated fruit was much lower (Table II). It required 75 fruits from the checks to produce an ounce of seed, whereas 168 fruits from hand-pollinated, unshaded plants were required to produce the same amount of seed. It is rather doubtful that so high a set can be obtained in the field as in the greenhouses, since drying of the styles is much more pronounced under field conditions.

Before the field harvest was complete, a severe freeze on the 6th of September damaged the immature fruits in the field. Consequently, the seed yield from the damaged fruits was computed proportionately to that of the matured fruits.

RESULTS 1944

The calculations on fruit set were based on clusters having from two to eight flowers each (Table I). The mean set for the field plants having all flowers in a cluster hand-pollinated was 63.9 per cent while the four-flowered clusters gave a mean set of 64.2 per cent. Open-pollinated field check plants had a much higher mean set of 78.8 per cent. Chi-square computations showed no significant difference for fruit set between hand pollination of all blossoms and four flowers per cluster. There was no significant difference in fruit set among

TABLE I—FRUIT SET UNDER EACH OF FOUR TREATMENTS FOR THREE- TO SEVEN-FLOWERED CLUSTERS IN 1943 AND TWO- TO EIGHT-FLOWERED CLUSTERS IN 1944

Experimental Conditions	Flowers Pollinated per Cluster (Number)	Clusters Pollinated (Number)	Flowers Set (Per Cent)	Chi-square Value
	Season of 1943			(df =4)
Greenhouse, hand-pollinated	3	22	74.3	
	4	21	83.3	
	5	17	78.8	
	6	12	75.0	
	7	8	73.3	
Mean	—	—	77.4	2.967†
Field, shaded, hand-pollinated	3	13	74.3	
	4	27	66.8	
	5	16	66.2	
	6	24	70.8	
	7	9	73.0	
Mean	—	—	69.6	1.730†
Field, unshaded, hand-pollinated	3	23	53.7	
	4	22	67.0	
	5	19	57.8	
	6	26	62.8	
	7	14	65.3	
Mean	—	—	61.9	4.174†
Check: field, unshaded, open-pollinated	3	21	65.0	
	4	72	61.8	
	5	89	64.0	
	6	45	58.9	
	7	16	60.7	
Mean	—	—	62.1	2,390†
	Season of 1944			(df =6)
Greenhouse, hand-pollinated	2	5	80.0	
	3	5	86.7	
	4	20	70.0	
	5	18	66.7	
	6	7	59.5	
	7	6	64.3	
	8	6	58.3	
Mean	—	—	66.4	6.429†
Check: greenhouse, open-pollinated	2	2	100.0	
	3	3	88.9	
	4	5	80.0	
	5	12	90.0	
	6	11	83.3	
	7	14	81.6	
	8	10	76.3	
Mean	—	—	82.5	5,768†
Field, unshaded, hand-pollinated	2	90	70.6	
	3	80	64.2	
	4	89	62.1	
	5	82	66.8	
	6	66	61.9	
	7	35	60.8	
	8	24	62.5	
Mean	—	—	63.9	7.382†
Check: field, unshaded, open-pollinated	2	7	71.4	
	3	19	82.5	
	4	27	87.0	
	5	39	76.9	
	6	47	77.7	
	7	43	78.1	
	8	22	78.4	
Mean	—	—	78.8	6.032†

†Not significant.

TABLE II—TIME INVOLVED IN POLLINATION FOR TOMATO SEED PRODUCTION IN EACH OF FOUR TREATMENTS IN 1943 AND 1944, BASED ON PER CENT OF FRUIT SET AND NUMBER OF FRUITS REQUIRED TO YIELD AN OUNCE OF SEED

Experimental Conditions	Flowers Pollinated (Number)	Flowers Set (Per Cent)	Weight of One Fruit (Ounces)	Fruits to Yield 1 Ounce Seed (Number)	Pollination Time	
					For 100 Flowers (Minutes)	For 1 Ounce Seed (Hours)
Season of 1943						
Greenhouse, hand-pollinated	314	75.12	2.51	120	68	1.8
Field, shaded, hand-pollinated	398	71.71	1.90	153	68	2.4
Field, unshaded, hand-pollinated	352	60.17	1.62	168	73	3.4
Check: field, unshaded, open-pollinated	791	60.24	2.03	75	—	—
Season of 1944						
Greenhouse, hand-pollinated	429	65.50	2.40	140	74	2.6
Greenhouse check: open-pollinated	429	80.65	2.70	—	—	—
Field, unshaded, hand-pollinated	4,210	63.37	1.20	189	61	3.0
Check: field, unshaded, open-pollinated	1,673	77.53	1.40	116	—	—

clusters of two to eight hand-pollinated flowers under field conditions. Greenhouse check plants showed that the five-flower cluster had a significantly higher set than the eight-flower cluster, but there was no significant difference among any of the others. The three-flower clusters showed a significantly (odds 19:1) higher set than the eight-flower cluster for greenhouse hand-pollinated plants, but none of the other clusters differed significantly. Plants in the greenhouse that were hand-pollinated had a mean set of 66.4 per cent for the two to eight-flowered clusters, whereas the open-pollinated check plants showed a mean set of 82.5 per cent.

In 1944, the difference in seed yield between the two field treatments was very slight. The number of fruits required for one ounce of seed from the four-flowered cluster treatment was 185 as compared with 189 fruits required to produce the same amount of seed from plants with all flowers in a cluster pollinated. Open-pollinated check plants in the field gave a higher seed yield, as only 116 fruits were required to produce one ounce of seed, whereas 140 fruits were required to produce an ounce of seed in the greenhouse from the hand-pollinated plants. Therefore, the number of fruit needed to produce an ounce of seed was considerably more for plants in the field than for those in the greenhouse.

CALCULATION OF TIME INVOLVED, 1943

Table II shows the comparative time involved to produce an ounce of hybrid seed under the different cultural treatments. The pollination work was done during the mornings. The time recorded for pollinating does not include the time required to uncover and cover the plants with cages in the field, but does include the time required for

tagging the clusters of pollinated flowers. As noted earlier, fewer hand-pollinated fruits were required to produce an ounce of seed in the greenhouse in comparison with hand-pollinated field-grown fruits. There was also a higher fruit set in the greenhouse as compared with the field-grown plants. The time for pollination varies depending on the treatment. Thus, in the greenhouse an ounce of seed was produced in 1.8 hours of pollinating time compared with 3.4 hours in the field. Shading the plants in the field reduced the time rate to 2.4 hours. In view of the difference between the two field treatments, it may be desirable to shade the plants under some conditions if the shading does not involve much expense for materials or much additional time. There is a greater seed yield from the shaded plants so that about 15 fruits less are required to make an ounce of seed than from those not shaded. If several hybrid seed lines are being produced, the use of cages would make it unnecessary to use isolation plots for the several lines. This would materially reduce cultural expenses. It should be noted that this part of the work was conducted on a small number of plants of a determinate vine type that normally sets very well under Cheyenne field conditions.

Calculation of Time Involved, 1944

Since there was only one person doing the emasculation and pollination of the plants in the field in 1944, most of the day was required to complete one pollination of all plants. Table II gives a summary of the results of the pollination time for the various treatments in 1944. To cross-pollinate 100 flowers, 74 minutes were required for the greenhouse plants, ~~while in the~~ field pollination time was reduced to 61 minutes. The pollination time to produce an ounce of hybrid seed in the greenhouse was calculated to be 2.6 hours while 3.0 hours were required to produce an ounce of seed in the field.

Discussion

Barrons and Lucas (3) showed that a little over 9 hours of pollination work was required to produce an ounce of hybrid tomato seed under their conditions. The present study indicates that with the materials and methods used at Cheyenne an ounce of seed could be produced with 3 to 4 hours of pollination work under field conditions. There are several factors that may be responsible for this reduction in pollination time. The emasculation and pollination methods used by the writers resulted in a large number of flowers successfully pollinated for a given time. The higher per cent of fruit set at Cheyenne in 1943 probably was partly due to the ideal temperature range during the pollination period. Only short periods of temperatures as high as 93 degrees F or as low as 50 degrees F were recorded. Smith and Cochran (14) have observed that the range between 70 and 85 degrees F is optimum for pollen germination and tube growth in tomato styles. Under the shade treatment at Cheyenne, the temperature range was between 58 and 90 degrees F. This favorable temperature factor and protection from the wind are probably partly responsible for the

higher percentage of fruit set under shade. A decrease in per cent of fruit set in 1944 probably resulted from unfavorable pollination conditions due to high winds that were prevalent throughout the summer. Unpublished data collected by the authors indicate that the inbred line used in this work produced an unusually heavy and early set of fruit as compared with many other varieties. As the data from the two field treatments in 1944 showed that there was comparatively little difference in time required for pollination of all flowers in a cluster as compared with only four flowers per cluster, there does not appear to be any significant advantage in pollinating a definite number of flowers in a cluster.

If varieties that set less readily or that have a smaller seed content are used as the seed parent; the time required to hand pollinate sufficient fruit for an ounce of seed would, of course, be correspondingly increased.

No attempt has been made to compute the total cost of producing an ounce of hybrid tomato seed, but preliminary work shows that it requires about 3.5 hours to pollinate sufficient flowers to produce an ounce of hybrid seed with the parents used in this work. The greenhouse treatment was included to determine whether a satisfactory seed yield could be obtained in the summer under glass when high temperatures are apt to occur. The results obtained in the greenhouse indicate that hybrid seed can be produced successfully during the summer months. Consequently, tomato growers who have greenhouses could use them to produce their own hybrid seed.

Since it has been observed that the number of seeds per fruit varies among seed parents the parent that is most prolific in seed production should be used as the female. This would aid in reducing costs.

Larson and Currence (9) showed that one of their most promising lines, Hybrid 3–38 x Valiant, in 1941 exceeded the higher yielding parent by 34 per cent in early yield and 19 per cent in total yield. They also found that this line averaged 22 per cent more than the highest yielding variety in total crop over a 3-year period. Unpublished data at Cheyenne show a similar relation between an F_1 hybrid and its parents. Consequently, the production and planting of hybrid tomato seed would appear of considerable importance, particularly when early yields pay big dividends as in market gardening.

Since there are about 8,000 seeds in an ounce of tomato seed, half an ounce would be sufficient to plant an acre under very favorable conditions of plant growth and an ounce should be ample under nearly all conditions. The extra cost of good hybrid seed to the market gardener would generally be more than offset by the increase in earlier yields resulting from its use. The use of certain F_1 hybrids would enable home gardeners to grow tomatoes in areas where their culture is now impossible because of short growing seasons.

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Field Identification of Genetically Male-Sterile Tomato Plants for Use in Producing F_1 Hybrid Seed

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PROGRESS in plant improvement depends largely on the amount of useful variation furnished by gene mutation. Most, if not all, varieties of beans, peas, tomatoes, and certain other crops were developed by selection and recombination of desirable mutations. Many mutants exist in the wild state; other genes, notably those of the sweet pea, have mutated during the period of cultivation (1). Since the genes of an individual mutate at random in most respects, the breeding of plants merely by selection of desirable mutants as they appear in cultivation is slow and fortuitous. This method is therefore seldom practiced except as the progressive plant breeder is constantly watching for useful mutants in his cultures. Although the mutation rate may be increased by certain treatments, especially short-wave radiation, it cannot be directed to produce only variations of a specific type. If crop improvement based entirely on selection of chance mutations is impractical, then the search for mutants of a specific type is generally far less feasible. The fertility relations of the tomato provide one of the rare instances in which a search for a useful specific type mutation, male sterility, is warranted.

Male-sterile mutants are potentially useful in hybridization of tomatoes (2), barley (12), onions (3), and sugar beets (9). Though surrounded by male-fertile plants, a male-sterile tomato plant sets very few fruits. Because this unfruitfulness induces taller vegetative growth, the male-sterile plant is conspicuous during the late harvest season, especially in fields of best growing conditions. Consequently, by scanning fields at this time, one can easily secure a large number of unfruitful plants even though they occur at the rate of only 1 per 1,000. The male-sterile mutants, which constitute about 5 per cent of all unfruitful types, can be identified without difficulty. In this manner not only can male-sterile tomatoes be found, but also they can be obtained with comparative ease in any desired variety. Male sterility was sought and found by this method in the varieties Early Santa Clara, Pearson, and San Marzano (11).

A random sample of 66 unfruitful plants in the three aforementioned varieties consisted of 45 triploids, 14 diploids, 3 tetraploids, 2 trisomics, and 2 haploids. The diploids, all apparently homozygous for recessive mutations, included 3 distinguishable types: plants deviating in gross morphology, whose sterility was presumably another effect of the genetype determining the morphological abnormality; plants having complete ovule and pollen sterility; and plants having normal or nearly normal ovule fertility and complete pollen sterility. Ovule fertility is reduced in one plant, but normal in the others, of the latter group. The male sterility of each of these plants (one in each variety) is conditioned by a single recessive gene (11).

Although the identification of male-sterile plants through breeding tests and by microscopical examination of chromosomes and development of gametes, is necessary for an exact classification of unfruitful plants, simpler and quicker methods may be used to sort out male-sterile mutants and to identify certain other types with reasonable accuracy.

Criteria for Field Identification of Unfruitful Types

The effect of various degrees of ploidy on the morphology of different plant species has often been described. As the degree of ploidy increases from haploidy to tetraploidy in tomatoes, the leaf shape changes from narrow to broad; the length-width ratio of fruits changes likewise, most noticeably in varieties having elongate fruits; the plant tends to branch less because axillary buds fail to develop; and, by virtue of increasing thickness, the leaves become darker green, and rougher and more brittle to the touch.

Leaf thickness, a character measured conveniently in the field, provides a reliable index of the degree of ploidy. Fig. 1 illustrates this relation in three populations of unfruitful plants. The thickness recorded for each plant is the mean of micrometer measurements of the lamina thickness of the terminal segment of the fifth leaf (from the growing point), longer than 1 inch, taken from 2 or 3 shoots. The frequency distributions of these means (Fig. 1) show that with one exception the measurements of haploid, diploid, and triploid-tetraploid groups do not overlap. As confirmed by later chromosome counts, each of these 110 plants was hereby classified correctly as to chromosome number, except 2 triploids (in population A) which fell in the diploid range. In the field one of these two exceptional plants was identified by its morphological characters as a triploid. As might be expected, the overlap of triploid and tetraploid groups is probably tôo great to permit their identification by this method. They can be distinguished, however, by their differences in fertility: the tetraploids set considerably more seedy fruits than the triploids.

Leaf thickness is influenced by factors other than degree of ploidy. The shift of the thickness ranges for each chromosomal type in population B, as compared with populations A and C, shows that the variety (genotype) may be an important factor. Plants which, for reasons of poor culture, grow more slowly often develop thicker leaves of comparable size than faster-growing plants. An environmental influence is also indicated by the fact that leaf thickness of plants grown in the cool, moist conditions of the winter greenhouse averages only 60 to 70 per cent as great as that of the same plants grown in the field under warm, dry summer conditions. That growing conditions may thus affect leaf development probably accounts for the misclassification of the triploids in population A and for other variation displayed in Fig. 1. For a given set of conditions in the average field, however, this method of identification proves workable when measurements are interpreted in conjunction with other characteristics of the plant.

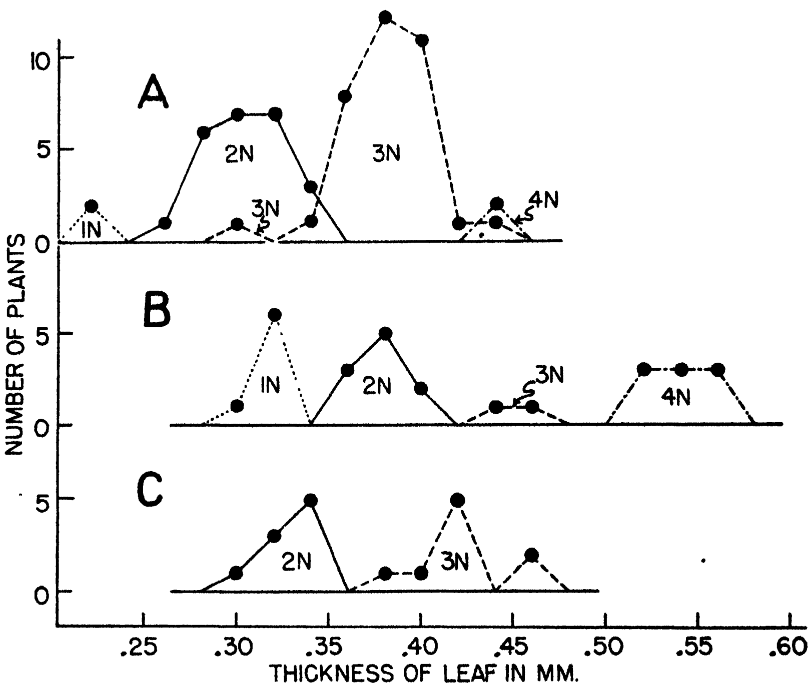

FIG. 1. Frequency distributions of leaf thickness for three populations of unfruitful tomato plants. (A) San Marzano, Thornton, California. (B) Early Santa Clara, Davis, California. (C) San Marzano, Clarksburg, California. The seven haploid individuals in population B are members of two clones.

The leaf thickness limits in the following key are given only as an example that might be used in classifying populations A and C, and are intended only as relative ranges for use in general. Thus, if a new field is to be scanned, one should first establish the diploid range by measuring leaf thickness of a sample of fruitful plants. Thicknesses below this range should indicate haploids; those above, the triploid-tetraploid group.

Part of the key depends on detecting the presence or absence of viable pollen. By forcing open the locules of a mature anther with a needle, one can easily determine whether pollen production is normal. Even if anthers produce pollen in normal amount but in aborted condition, the amount extruded by this method will appear much less than normal. By this method the four previously described male-sterile mutants (10, 11) can be distinguished from male-fertile plants without difficulty. A lighter color and a slightly shrunken condition of the anther are also characteristic of these mutants. The male-sterile type described by Lesley and Lesley (5) could not be distinguished by this method, since its pollen is normal even in microscopic appearance except for slightly smaller mean size and

starch reaction in IKI stain. As more unfruitful plants are examined, male sterility of the latter type may be encountered more often; it would, obviously, be misclassified in the following key. Probably, however, male sterility of this type would not be useful for hybrid seed production: the very difficulty of field identification that leads to misclassification in the key would hamper identification of male sterility in plants intended for large-scale plantings.

For convenience, aneuploids and plants homozygous for mutations affecting habit and foliage are screened out in one group. According to Lesley (4), trisomic and less balanced tomato aneuploids differ from diploids in color and shape of leaves and in size or habit of plant. Although in a few trisomic types (notably triplo-E) these differences are not marked, those plants that might thus be misclassified in the key constitute a very small proportion of all unfruitful plants.

Plants that owe their unfruitfulness to mutations conditioning irregular meiosis might also be misclassified in the following key. A plant exhibiting asynaptic meiosis, the only example of this kind encountered in the present work (11), was completely sterile both in pollen and ovules. Being classified with "completely sterile mutants" in the key, it would not be confused with "male-sterile mutants;" nevertheless, asynaptic and other irregular meiotic mutants having low ovule fertility are known in other species. If found in tomatoes, however, they should not be confused with male-sterile mutants, because the latter would exhibit much higher ovule fertility.

Key for Identifying Cyto-Genetic Types of Unfruitfulness

Foliage and habit of plant normal.
- Leaves 0.20 to 0.25 mm thick; plant usually small and compact but erect .... *haploids.*
- Leaves 0.25 to 0.35 mm thick; plant usually very large and spreading .... *diploids.*
  - No fruits with seeds produced by natural (or artificial) self or cross-pollination .... *completely sterile mutants.*
  - Fruits with seeds produced by natural (or artificial) self or cross-pollination.
    - Viable pollen produced; deviation in structure of flower, fruit, or other parts .... *morphological mutants.*
    - No viable pollen produced; normal morphology of all parts except for reduction of anthers .... *male-sterile mutants.*
- Leaves 0.35 to 0.50 mm thick; plant usually large, erect, and straggly.
  - Fruits average less than 2 seeds each .... *triploids.*
  - Fruits average 2 or more seeds each .... *tetraploids.*

Foliage and habit of plant deviating from normal .... *aneuploids and mutant diploids.*

The identification of male-sterile mutants by use of the key should subsequently be checked by breeding tests. The necessary information can be provided by small F_2 and backcross progenies, which can be secured readily as outlined in the following program.

Utilization of the Male-Sterile Mutants

At the time male-sterile plants are identified by these methods, it is usually too late in the season to complete any controlled crosses. Nevertheless, in all examples observed by the writer, natural crossing has been sufficient to permit male-sterile plants to produce several seedy fruits. Since these plants yield no viable pollen, any seeds produced must result from outcrossing to surrounding male-fertile plants. If a winter generation in the greenhouse is grown from these hybrid seeds and from cuttings of the male-sterile plants, selfings and crosses may be made in order to have F_2 and backcross generations of fair size for testing in the field the following season. Thus one can secure populations of male-sterile individuals in a desired variety in less than one year by this method, whereas five or more years would be required under the familiar backcross system.

The advantages of male-sterile plants over emasculated male-fertile ones in mass production of F_1 hybrid seed are obvious. No labor would be required for emasculation. Male sterility, being completely recessive, will not appear in the F_1 hybrids or in any way reduce their fertility. If emasculated male-fertile plants are used as pistillate parents, there is considerable risk of contamination by self-pollination. On the other hand, the only risk of contamination involved in the use of male-sterile plants is natural crossing by some undesired parent. One could turn natural crossing to advantage, however, by interplanting the male-sterile plants with the desired pollen parents, isolating the whole planting sufficiently from other sources of pollen.

The male-sterile line should be perpetuated in each generation by backcrossing male-sterile plants to heterozygous male-fertile sibs. Since these backcross populations yield approximately equal numbers of male-sterile and male-fertile plants, twice the needed number of plants must be grown. In tests here, the first flowers produced by tomato seedlings have been trustworthy indicators of male fertility or sterility. It would accordingly be efficient to grow seedlings to the flowering stage in frames or flats, thereafter transplanting to the field only the male-sterile plants as identified by the appearance of their anthers.

These findings offer no solution to the problem of pollen transfer from male-fertile to male-sterile plants. Natural crossing at the known rates for tomatoes is too inadequate to serve as the pollination agency; however, certain pollination techniques, such as those described by Barrons and Lucas (2), could be devised to reduce greatly the labor required in hand pollination.

Aside from their potential usefulness in producing F_1 hybrids for immediate commercial use, male-sterile mutants can be employed to advantage in mass production of hybrids for other purposes. Thus, the yield of viable seed is very low in certain interspecific crosses,

such as the *L. esculentum* x *L. peruvianum* combination, which offers new possibilities in the breeding of disease-resistant tomatoes. Embryo culturing can be used to circumvent this difficulty (13). Where this technique cannot be used, however, it might be possible, in view of the great variation in embryo development observed, to secure a few hybrids by making pollinations on a large scale. The same embryo lethality hampers the backcross between this hybrid and its *esculentum* parent; yet by backcrossing on a large scale, seedlings have been obtained. The extreme selection of seedlings entailed by this method might aid in fixing, as rapidly as possible, an *esculentum*-compatible type, and might be desirable for other reasons.

Utilization of Other Unfruitful Types

Studies of unfruitful plants have uncovered heteroploids and new gene mutants that should be helpful in further cyto-genetic studies of the tomato.

The larger fruit size and differences in quality of the fruit and adaptation of the plant might render the tetraploid tomato useful material for the plant breeder. Until their disturbingly high sterility is overcome, however, such tomatoes are not likely to have any horticultural value.

The derivation of pure-line tomatoes by doubling the chromosome number of haploids has been accomplished by Lindstrom and Koos (6) and Newcomer (8). Diploid seedlings that were obtained from haploids by Morrison (7) should also be members of pure lines if the seeds were set on the haploids as a result of self-pollination. Likewise, in the present work, diploid clones derived from two haploids of the variety Early Santa Clara should be the foundation for completely homozygous lines. Although pure lines can be produced readily from haploids identified in the field by use of the key, they would seem less useful in tomatoes than in cross-pollinated crops. Inbreeding of the latter group usually yields a very high proportion of weak genotypes. Considering also that haploids generally are much weaker than diploids derived from them, any haploids that survive in these crops should represent the product of extreme selection for vigorous genotypes. On the other hand, being naturally inbred to a very great extent, most tomato plants are members of pure lines or nearly pure lines; moreover, a whole variety may represent a single pure line when it has been repeatedly subjected to single plant selections. This use of haploids would, therefore, seem to have little practical value in tomatoes except to eliminate undesirable variation generated by the low but appreciable mutation rate of this crop (11).

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Sabadilla, an Insecticide to Control the Squash Bug

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SABADILLA, a new insecticide dust manufactured in accordance with techniques developed at the Wisconsin Experiment Station, has shown exceptional promise in the control of some crop insects.

The insecticide is prepared by activating or finally grinding the seed and diluting with sulphur or talc (pyrophyllite), the nature of the diluent depending upon the crop for which the insecticide is intended.

The dust at varying concentrations has exhibited strong toxic properties against some of the most resistant insects not responding to present commercial control methods. Such insects as the Squash bug (*Anasa Tristis* De Geer) Lygus bugs, and the Harlequin bug have been controlled successfully with Sabadilla.

In 1944, in cooperation with a manufacturer of the insecticide, a series of trials were conducted in Utah County to observe the affects of this insecticide on Squash bugs as measured against check plots. Nine commercial varieties were observed. The dust was applied freely among the seedlings in two different applications, 15 days apart.

Typical of the yields obtained are those of the Golden Delicious variety of squash, which yielded approximately 11 tons per acre while the check plots averaged only 3.75 to 4 tons per acre (Table I).

TABLE I—EFFECT OF SABADILLA ON YIELD OF GOLDEN DELICIOUS SQUASH THROUGH CONTROL OF THE SQUASH BUG

Treatment	Plant Survival	No. of Fruits	Average Weight (Pounds)	Yield (Tons Per Acre)
Treated	15	18	6.02	11.11
Treated	15	16	6.3	11.34
Check	5	6	5.65	3.75

Experiment stations cooperating on the study of Sabadilla report the insecticide to be several times as toxic to the squash bug as pyrethrum, of which the supply has been cut off due to the war. Pyrethrum was slow in its killing properties even though it came into direct contact with the insect during the dusting operation. Experimental evidence would indicate that Sabadilla, applied well around all vines, gave excellent control and seemed to have residual properties as the migrating insects entering the field avoided the treated plots.

More research is necessary to fix the concentrations for various crop insects. For the Squash bug, a concentration of 20 to 30 per cent of activated material gave satisfactory control.

Use of the Refractometer for Selecting Onion Bulbs High in Dry Matter for Breeding[1]

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Method of Sampling

The dry-matter content of onions is of considerable importance in varieties used for dehydration. The development of desirable lines involves selection of individual bulbs containing a known amount of dry matter. This type of selection presents some special problems. As a rule, onions for breeding are grown from seed the first year to produce bulbs of marketable size, which are inspected for desired characteristics. Selected bulbs are planted out the following year for seed production. In determining the dry-matter content of individual bulbs, one must remove a portion of the bulb for analysis. A sample, representative of all the tissues, will consist of a sector limited by cuts parallel to the axis of the bulb. When bulbs thus sampled are set out in the field or are placed in storage to be planted later, spoilage organisms enter the wounds caused by sampling and many bulbs are lost. Since these are selected from large populations, such losses are serious.

To avoid spoilage, other methods of sampling have been tried. The two outer-most fleshy bulb scales may be removed with very slight injury, and bulbs thus sampled may be planted with little danger of loss from spoilage.

That the outer fleshy scales are not representative of the dry-matter content of the whole bulb has been shown by Zeller (2). For sugars, which constitute much of the dry matter of the onions, he found that the concentration increases from the outside toward the center of the bulb and from the top toward the base.

The following experiment indicates the magnitude of the gradient in dry matter between the inner (younger) scales and the outer (older) scales of the onion bulb. From a commercial lot of Southport White Globe onions two samples were selected, one of large and one of small bulbs. For both these samples, all dry and partly dry outer scales were removed, and the bulbs were then divided individually into three approximately equal portions, the outermost, middle and innermost scales. The fresh weight and the per cent dry weight of these portions were determined (Table I).

The per cent dry weight increases from the outer to the inner scales. Comparison was made of per cent dry weight in each bulb (that is, innermost vs. middle or middle vs. outermost scales). In only 2 out of the 46 possible comparisons for the 23 bulbs was there a reversal of the order shown in Table I.

Although this table shows that dry-weight determinations from the outer scales cannot be used for the whole bulb, the dry weight of the

[1]This work was supported in part by a grant from the Basic Vegetable Products Co., of Vacaville, California.

TABLE I—Per Cent Dry Matter in Various Portions of the Bulbs of Two Samples from a Commercial Lot of Southport White Globe Onions*

Size of Bulbs	Number of Bulbs	Mean Weight of Bulbs (Grams)	Mean Fresh Weight of Parts			Mean Dry Matter of Parts			Mean Dry Matter of Whole Bulb (Per Cent)
			Outer (Grams)	Middle (Grams)	Inner (Grams)	Outer (Per Cent)	Middle (Per Cent)	Inner (Per Cent)	
Large	12	113.1±11.3	16.5	14.9	22.7	11.1	12.3	14.0	12.6 +2.17
Small	11	45.7± 7.46	8.70	8.30	9.34	11.2	11.9	14.4	12.47±1.38

*Values following means are standard deviations.

whole may be estimated from that of the outer scales, provided the relation between the two is sufficiently constant.

Fig. 1 shows the regression of per cent dry weight of the whole bulb on the per cent dry weight of the outer portion. The data from both large and small bulbs (Table I) were used. One point (6.2, 10.5) was omitted from both Table I and Fig. 1.

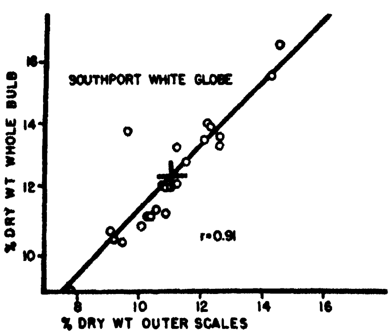


Fig. 1. Regression of per cent dry weight of the whole bulb on the per cent dry weight of the outer scales, using combined data of large and small bulbs as given in Table I. Points represent values from single bulbs. Standard error of estimate (Sy.x) = 0.76 per cent.

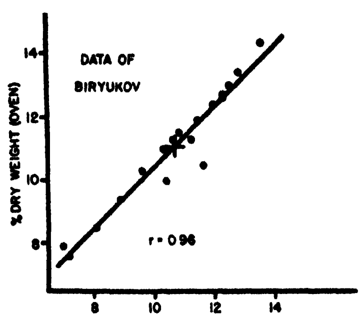


Fig. 2. Regression of dry weight (oven) on dry weight (determined by refractometer) from 18 varieties and lines as calculated from data of Biryukov (1). Each point represents a sample of five bulbs. Standard error of estimate = 0.50 per cent.

Use of the Refractometer

Biryukov (1) has shown that the refractive index of onion pulp is related to dry-matter content. Calculation from his tabular data shows a correlation of r = 0.96 for dry weights (oven) on refractometer readings (unspecified units) of pulp for five bulb samples from 18 varieties and lines. Fig. 2 is based upon Biryukov.

Since refractometer readings are readily taken, experiments were made to determine whether the dry-matter content of individual bulbs could be satisfactorily estimated from a refractometer reading of the

juice of the outer scales. Determinations were made in the following manner. The per cent dry weight of the whole bulb was determined by drying a sector of a bulb from which all dry or partly dry scales had been removed. For refractometer readings, a sample of the two outermost fleshy scales of the remainder of the bulb was chopped, placed in a double layer of cheesecloth, and crushed with a pestle against a thick glass plate. A small amount of juice was squeezed through the cloth to the plate of a Zeiss hand sugar-refractometer. The readings (expressed as percentage concentration of a sucrose solution) are used as arbitrary figures for correlation against per cent dry weight of the whole bulb.

Refractometer readings and per cent dry weight were taken individually on the outer fleshy scales of a sample of 29 bulbs of Southport White Globe. The per cent dry matter of the whole bulb was also determined. Fig. 3 shows regression lines based upon these data. For this sample the per cent dry weight of the whole bulb could be estimated just as well from the refractometer reading of the outer scales as from their oven-determined per cent dry weight.

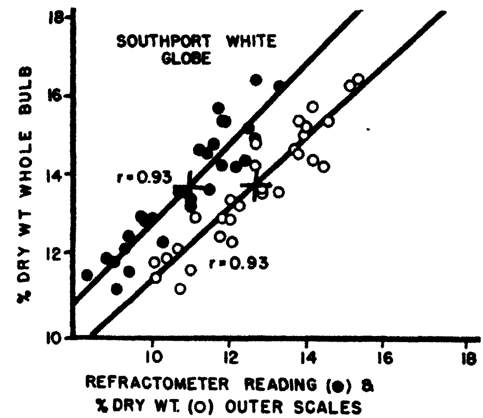


FIG. 3. Regression of per cent dry weight (oven) of whole bulb on (1) refractometer reading of juice of outer scales and (2) oven-determined per cent dry weight of outer bulb scales. Points represent values from single bulbs. See Table II.

Southport White Globe onions grown under different environments from those considered in Figs. 1 and 3 were examined. Data were also taken on other varieties that differed widely in dry-matter content.

Fig. 4 (Southport White Globe, Lot 1) utilizes data on Southport White Globe onions from several different fertilizer treatments and two seed sources. These data were chosen to represent a sample grown under a very nonuniform environment. Further data on Fig. 4 (Southport White Globe, Lot 1) appear in Table II.

The Southport White Globe onions from which data were drawn for Fig. 4 (Southport White Globe, Lot 2) were grown from the same seed lot as those of Fig. 3. The field conditions were much more uniform for the onions represented in Fig. 4 (Southport White Globe, Lot 1'). See Table II for further information. Figs. 4 and 5 give regression lines for additional samples examined. See Table II for data on these samples also.

Fig. 5 (Italian Red) is based on a variety very low in dry matter. This was clonal material of a male-sterile line, "13–53". Compared with Fig. 1 and Figs. 3 through 5 (California Early Red and Aus-

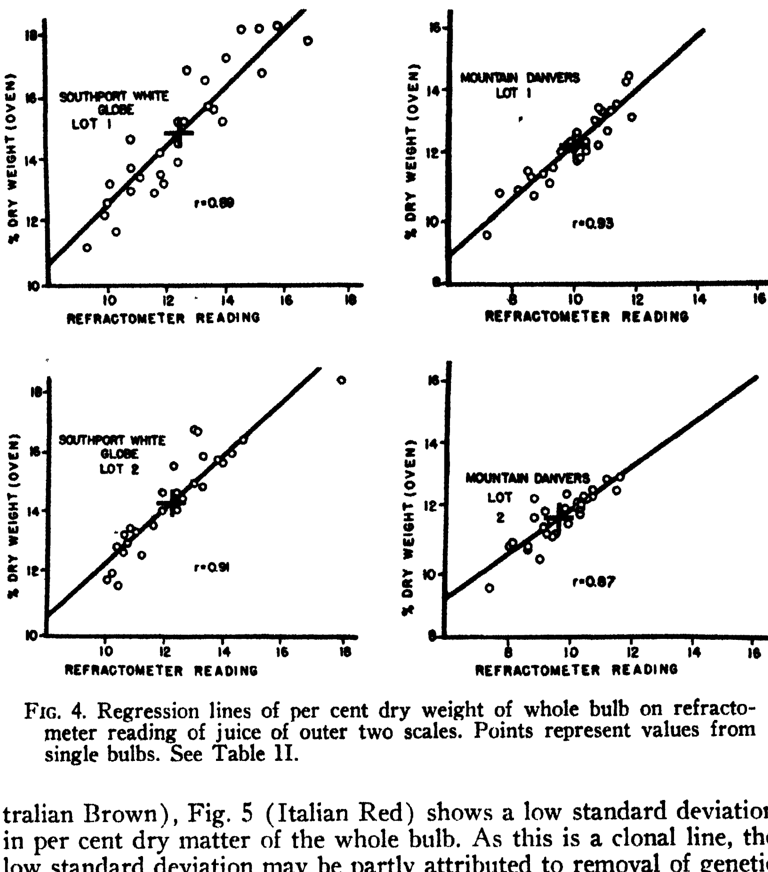
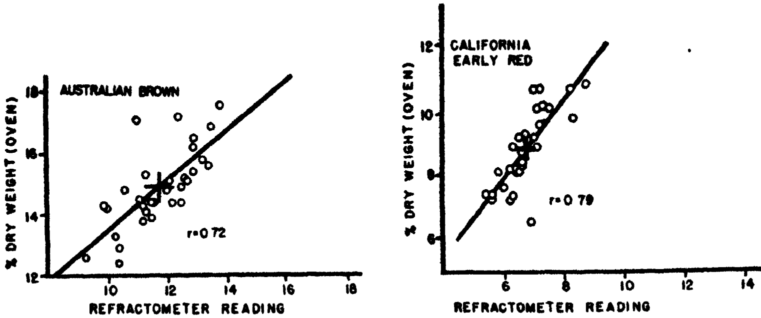


FIG. 4. Regression lines of per cent dry weight of whole bulb on refractometer reading of juice of outer two scales. Points represent values from single bulbs. See Table II.

tralian Brown), Fig. 5 (Italian Red) shows a low standard deviation in per cent dry matter of the whole bulb. As this is a clonal line, the low standard deviation may be partly attributed to removal of genetic variation. Since, however, no commercial strain of Italian Red was available for comparison, the reduction in variation can hardly be estimated. Further data may be found in Table II.

SIZE OF BULB AND PER CENT DRY MATTER WITHIN VARIETIES

Table I gives the mean per cent dry matter for a sample of large bulbs (12.6 per cent) and a sample of small ones (12.5 per cent) drawn from the same population. The difference in these values is very slight. For other onion samples examined, correlation between the fresh weight of the individual bulbs and their per cent dry matter was determined. Even though bulbs were selected to give a large variation in fresh weight (see standard deviation of bulb weight, Table II) no value of r is significant (5 per cent) except that of clonal Italian Red, which exceeds the 1 per cent level (Fig. 6). For the sample of Southport White Globe onions whose data appear in Fig. 3, the correlation is only slightly below significance (5 per cent). Per-



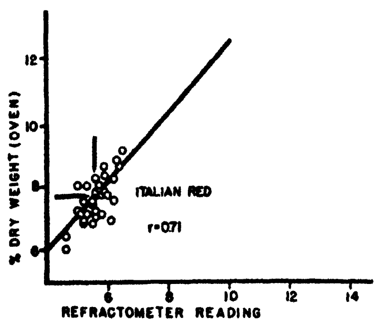


FIG. 5. Regression lines of per cent dry weight of whole bulb on refractometer reading of juice of outer two scales. Points represent values from single bulbs. See Table II.

haps with larger samples, a significant correlation might be found for most varieties. Where, however, one must examine bulbs individually, as in selecting them for breeding, apparently one would gain little by attempting to adjust for bulb size.

Size of Bulb and Dry Matter Among Varieties

For the few varieties examined here, it was noted that those with low mean dry matter had relatively large bulbs (Italian Red and California Early Red), while varieties high in dry matter had smaller bulbs (Southport White Globe and Australian Brown). A regression line was calculated from the data available (see Table II for the eight pairs of means) and the correlation coefficient $(r) = -0.86$, which is above the 1 per cent level significance. Since, however, many factors affecting the bulb size (time of planting, environment during growth, and, finally, selection of sample), this suggestion will have to be checked by further observations.

Use of the Refractometer on Samples of Unknown Characteristics

The data thus far presented indicate that for individual bulbs within a sample, high refractometer readings are associated with high per

TABLE II—ADDITIONAL DATA ON REGRESSION LINES SHOWN IN FIGS. 3 THROUGH 5*

Variety and Text Figure	Area Where Grown Date Harvested	Date Analyzed	Number of Bulbs Used	Fresh Weight of Bulbs (W) (Grams)	Per Cent Dry Weight of Bulbs (Y)	Refractometer Reading** Juice Two Outer Scales (X)	Correlation y and x	Standard Error of Estimate	Correlation y and w
			n	w ± Sw	y ± Sy	x ± Sx	r	Sy.x	r
Southport White Globe, Fig. 3	Davis, Calif.	———	29	56.08 ± 14 48†	13.77 ± 1.48	10.88 ± 1.37	+0.93††	0.57	−0.35
Southport White Globe, Fig. 4 Lot 1	Tulelake, Calif. Sep 28, 1944	Oct 6, 1944	29	82 38 ± 25.11	14.60 ± 2.05	12.44 ± 1.89	+0.89††	0.93	−0.05
Southport White Globe, Fig. 4 Lot 2	Tulelake, Calif. Sep 28, 1944	Oct 20, 1944	29	98.07 ± 28.19	14.45 ± 1.66	12.32 ± 1.74	+0.91††	0.70	−0.04
Australian Brown Fig. 5	Davis, Calif. Jul 21, 1944	Oct 5, 1944	31	80 54 ± 25.92	14.78 ± 1.28	11.64 ± 1.16	+0.72††	0.91	+0.15
Mountain Danvers, Fig. 4. Lot 1.	Tulelake, Calif. Sep 28, 1944	Oct 5, 1944	30	97.20 ± 37.47	12 26 ± 1.12	9.99 ± 1.22	+0.93††	0.41	−0.36
Mountain Danvers, Fig. 4 Lot 2.	Tulelake, Calif.	Nov 6, 1944	29	101.21 ± 24.71	11.72 ± 0.81	9.68 ± 1.04	+0.87††	0.41	+0.04
California Early Red, Red No. 1. Fig 5	Davis, Calif. Jul 6, 1944	Early Sep	30	155.13 ± 64.11	8.81 ± 1.23	6.75 ± 0.78	+0.79††	0.76	+0.12
Italian Red, "male sterile 13–53", Figs. 5 and 6	Davis, Calif.	Sep 15, 1944	35	136.7 ± 72.48	7,62 ± 0.69	5.63 ± 0.51	+0.71††	0.48	−0.51††

*Values following means are standard deviations.
**Expressed as per cent concentration of a sucrose solution.
†Based on 25 bulbs.
††Significant at the 1 per cent level

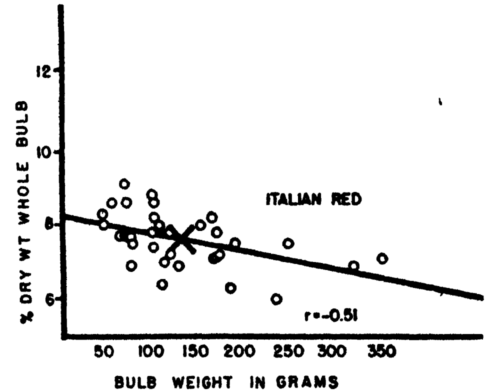


FIG. 6. Regression of per cent dry weight (oven) of whole bulb on fresh weight of bulb in grams. Each value represents a single bulb.

cent dry weights. One can select for high dry matter on this basis without knowing the actual per cent dry matter of the bulbs. If one wishes to know the approximate per cent dry matter, the following question arises: How well may regression lines, worked out for known varieties, apply to samples of unknown characteristics?

Fig. 7 shows the regression lines for eight samples (from Table II) all placed on a single graph. The lines tend to be parallel. Evidently, then, a refractometer reading, unusually high for a low dry-matter variety and unusually low for a high dry-matter variety, will indicate, for either of them, about the same per cent dry weight. That is, according to the samples here examined, an approximate single regression line can be used for all varieties. This regression line, drawn through the mean values of Fig. 7, is shown in Fig. 8. The regression equation for this line is $E = 1.076X + 1.58$.

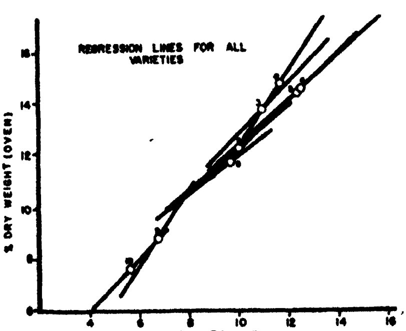


FIG. 7. Regression lines of per cent dry weight (oven) on refractometer reading of juice of two outer scales. Composite graph of Figs. 3 to 5, inclusive.

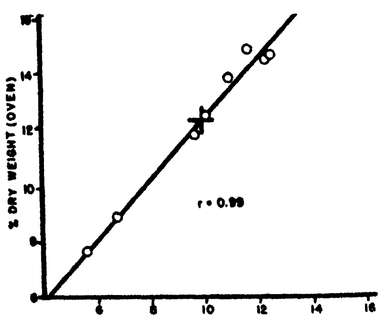


FIG. 8. Regression line of per cent dry weight (oven) on refractometer reading of juice of two outer bulb scales. Line drawn among mean values shown in Fig. 7.

For varieties or strains on which no specific data are available, one can use Fig. 8, a generalized curve from all the data at hand, to estimate the dry-matter content of bulbs from the refractometer reading of the juice of the outer scales. For such varieties or strains this curve

may be expected to be less accurate than are Figs. 4 through 5 when used with the varieties that they represent.

Summary

1. Sampling of breeding stock onion bulbs for dry-matter by removing a sector of tissue results in wounding, followed by spoilage in the field or in storage.

2. The two outermost fleshy scales may be removed with very little injury to the bulb. Although these outer scales do not constitute a representative dry-weight sample, their dry weight is sufficiently well correlated with bulb dry weight to be practical for breeding purposes.

3. The refractometer reading of the juice of the two outer fleshy scales is easily obtained and is as well correlated with the per cent dry weight of the bulb, as is the per cent dry weight of the outer scales.

4. Regression lines of the per cent dry weight of the whole bulb on refractometer readings (expressed as per cent concentration of a sucrose solution) of the juice of the two outer scales are given for several varieties (Southport White Globe, Australian Brown, Mountain Danvers, California Early Red, and a clonal strain of Italian Red).

5. Within some varieties, a significant correlation was found between fresh weight of the bulbs and their per cent dry matter. In selecting bulbs for breeding, however, one would probably gain little by attempting to adjust for bulb size in estimating per cent dry weight.

6. For the samples examined, varieties with relatively low per cent dry weight had large average bulb size. On this point, further observation is needed.

7. On the basis of samples here studied, a curve for regression of per cent dry weight of whole bulb on refractometer readings of juice of the outer scales is given. This would seem suitable for approximation for most onion varieties.

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Dent, Flint, Flour and Waxy Maize for Improvement of Sweet Corn Inbreds[1]

By E. S. HABER, *Iowa Agricultural Experiment Station, Ames, Iowa*

CONSIDERABLE interest has been shown by sweet corn breeders in the use of other types of corn for improvement of sweet corn inbreds. Can vigor, resistance to diseases and insects, drouth resistance, etc., be incorporated into sweet corn inbreds through the use of crosses with other types of corn and still maintain quality in the sweet corn inbreds and the resulting hybrids from these inbreds?

The writer undertook a program of breeding in 1933 involving field and sweet corn crosses. Until January of 1945 no sweet corn inbreds have been released from the Iowa Station which had field corn "blood" in them. In January, 1945, one Evergreen inbred, 3005, the ear parent of the hybrid Iogreen 56 was released. The work has progressed far enough that the writer can definitely recommend this program as a means of improving sweet corn inbreds.

It is preferable, when available, to use inbred field corn lines for crossing with the sweet corn lines. In the development of the field corn inbreds, many of the defects and deleterious characters have been eliminated by the breeders. Open-pollinated field corn varieties have not had these undesirable characters eliminated and slower progress is made with them when they are used in the breeding program.

Usually it is desirable to back-cross the sweet corn inbred to the F_1 hybrid of the field x sweet cross at least once or twice before selfing. If the sweet corn inbred is back-crossed more than twice, there is little chance for selection when the "selfing" is initiated. The hybrid which has been back-crossed 3 or more generations to the original cross will appear to be so nearly like the original sweet corn inbred that there is little chance for selection of a line which will not have the poor characters of the original line and will not have the desirable characters of the field corn line that the breeder is trying to incorporate into the sweet corn line. It is necessary to carry a large number of sister lines from crosses involving field and sweet corn in order to obtain quality in the recovered sweet corn line. It is true that undesirable flavors, color, and toughness of kernels may be incorporated into the sweet corn if great care is not exercised in discarding corn with such characters. If enough sister lines are maintained, those having poor quality can be eliminated.

Tough pericarp, a character frequently associated with field x sweet corn crosses in the minds of many people, can be eliminated readily or not incorporated. There are field corn inbreds which have a relatively tender pericarp which can be used.

Toughness of pericarp can be measured by mechanical means or "chewing" test and quality by means of "chewing" test or roasting

[1]Journal Paper No. J-1289 Project 293, Iowa Agricultural Experiment Station.

ears at the edible stage, but a canning test is necessary, also. Sometimes undesirable flavors or colors develop in the processing.

The following types have been used with sweet corn and some of the recovered inbreds are homozygous and have been tested with promising results. L317, a dent corn line used in many commercial field corn hybrids, has proved to be out-standing when crossed with sweet corn in incorporating drouth resistance, plant vigor and yield in the sweet corn inbreds. Evergreen inbred 3005, used in Iogreen 56, was found to be highly resistant to drouth. Dr. R. C. Eckhart, stationed at the Mississippi Agricultural Experiment, reported Iogreen 56 to withstand the drouth of 1944 in that state when practically all other sweet corn hybrids failed. In using L317, some sister lines will segregate which have undesirable color, particularly after processing.

Dent inbreds Os 420, Os 426, Krug 187 and 164 have proven to be good. They are used in commercial field corn hybrids because of their combining ability. Lines with tough pericarp segregate and must be carefully checked and eliminated. Dent inbreds Pr, R_4 and Hy have not proven particularly useful, but this may have been due to the few sister lines recovered and maintained. Most of the good dent inbreds have red cobs and it is necessary to eliminate this character from any recovered sweet corn lines as red cobs are undesirable in commercial sweet corn hybrids used by canners.

Some of the flint varieties are valuable. Howe's Alberta Flint, Falconer, Mammoth Canadian (yellow and white strains), Manalta, Longfellow, Triumph and Smut Nose have been used. The last named always imparted undesirable color to the recovered lines. Howe's Alberta Flint is as early or perhaps earlier than any sweet corn and has proved valuable in developing very early inbred sweet corn lines. With some of the other flint varieties added ear length in early and mid-season inbreds has been secured. Kutias flint has proven valuable and several sweet inbreds with high sugar content have segregated from the original cross.

Several flour corn varieties such as Navajo from southwest United States and others from Mexico and Central America have extremely heavy husks which may have some value in corn ear worm resistance.

Several years ago, waxy-sweet crosses were made to incorporate the waxy type of starch in the sweet corn lines with the thought that they might remain in the edible or canning stage a longer period of time. This doesn't appear to be the case so far and sweet inbreds containing the waxy type rather than the ordinary type of starch dry slowly in the seed stage in the field and are susceptible to soft corn rots.

In conclusion, the writer is of the opinion that much can be gained in improving sweet corn inbred lines when crossed with suitable lines and varieties of field corn. A great deal of care must be exercised in selecting the recovered sweet lines to avoid poor quality in the kernels.

A Note on "Tsontsai"

By Von Gee Sun and L. C. Sze,[1] *National University of Chekiang, Meitan, Kweichow, China*

"Tsontsai" occasionally is cultivated as a vegetable in Meitan, Kweichow, China. It was classified as a variety of *Brassica juncea*, Coss. by the senior author (1942) who suggested the name *Brassica juncea*, Coss. var. *linearifolia*, Sun. The plant was first discovered in 1940 by the staff members of the Horticultural Department of the National University of Chekiang. The senior author has examined its morphological characteristics and has made crosses with other varieties of *B. juncea* and other species of Brassica. The junior author made cytological examinations of the plant and of F_1 crosses with other varieties of *B. juncea*. This paper will present a detailed description of the plant together with data on the F_1 crosses between Tsontsai and its related forms, and cytological studies of the parents and hybrids, as a basis for deciding that Tsontsai is a variety of *B. juncea.*

Morphology of the Plant

"Tsontsai" is an over-winter annual in Meitan. Mature plant height about 100 cm; profusely branched near the ground; stem weak, slender, more or less glaucous, apt to lodge under heavily manured or stormy conditions; radical leaves dark green, glabrous, slender, linear, petioled, with upper part entire, lower part irregularly notched as shown in Fig. 1; upper stem leaves very thin, slender, petioled, almost without blade; root and stem without tuber-like formation; flowers bright yellow, small; petals 11–12 mm long, 5 mm wide; sepals separating or spreading; pollen size large, from 41.49–44.80 μ in length and 29.30–29.71 μ in width based upon samples of 5 and 25 in measurements made during two seasons; sillique short, 28–35 mm long, mean length 31.5 mm; beak 5–8 mm long, mean length 7.3 mm; seeds reddish brown, very small, 50 seeds weighing only 0.0275 gram. The plant is highly self-fertile when the inflorescence is bagged.

Crossing with Other Varieties or Species of Brassica

Tsontsai can be crossed readily with other varieties of *B. juncea* but it is difficult to cross with other species of Brassica. The results of hybridization in 1941 were as follows:

Parental combinations	Number Flowers Pollinated	Sillique Obtained	Seeds Obtained
Tsontsai x Snowball (*B. rapa*, L.)	10	1	1
Shealiehontsai (*B. juncea*, Coss.) x Tsontsai	10	7	17
Tsontsai x Shealiehontsai	15	14	167
Tsontsai x Tayutsai (*B. juncea*, Coss.)	15	13	183
Tsontsai x Tayutsai (*B. juncea*, Coss.)	10	—	46
Tayutsai x Tsontsai	10	—	20

[1]The writers wish to express their thanks to Professor C. C. Tan for his assistance in the interpretation of the cytological data.

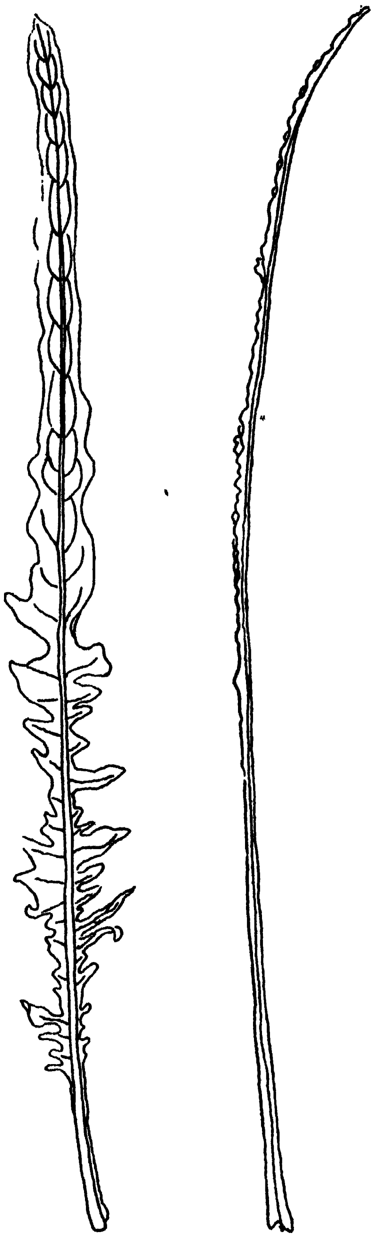

FIG. 1. Leaves of Tsontsai: left, radical leaf; right, stem leaf. (about ¼ natural size)

Not a single F_1 plant was obtained from the cross between Tsontsai x Snowball. From the varietal crosses a number of F_1 plants were raised in 1942. All F_1 plants appeared to be vigorous and highly self-fertile either bagged or under open pollination. The leaf shape, as shown in Fig. 2, of the hybrid between Tsontsai and Shealiehontsai and of Tsontsai x Tayutsai both appeared intermediate between their respective parents. It may be noticed that the two intermediate hybrid types are very different from each other, probably due to the different combinations of parental genes.

Pollen grains of the respective F_1 plants were collected and measured at anthesis time. They all appeared uniform in shape and size. In no case was abortive pollen found. The mean length and width of pollen grains based upon 25 measurements for each parental type as well as their respective hybrids are given in Table I.

The pollen size of F_1 plants appears to be intermediate between their respective parents, the only exception being found in the cross between Tsontsai and Tayutsai where the length of the pollen grain is significantly longer than that of either parent.

Cytology of the Plant and Its F_1 Hybrid

Cytological investigations were carried out in the spring of 1942. For the preparation of slides the ordinary acetocarmine smear method was employed. All figures were drawn with the aid of a Leitz camera lucida, using a Zeiss ocular x28 and a Zeiss oil immersion objective x90 to give

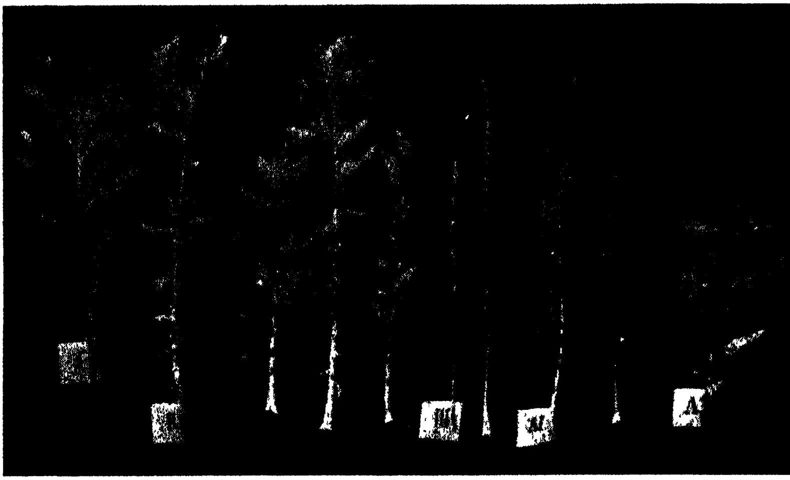

FIG. 2. Leaves of Shealiehontsai, Tsontsai, Tayutsai, and F_1 crosses of Tsontsai x Shealiehontsai and Tsontsai x Tayutsai: I, Shealiehontsai; II, Tsontsai x Shealiehontsai; III, Tsontsai; IV, Tsontsai x Tayutsai; V, Tayutsai. (about $^{1}/_{20}$ natural size)

a magnification of about x2520. As shown in Fig. 3A, the number of bivalents observed in the first metaphase of Tsontsai is 18, similar to the gametic chromosome number of known varieties of *Brassica juncea* as has been previously reported (Gaiser, 1933). The identity in the chromosome number between Tsontsai and known varieties of *Brassica juncea* was further confirmed through the studies of the hybrid meiosis between Tsontsai x Shealiehontsai, a variety of *B. juncea* (Figs. 3B, 3C, 3D) in which again 18 bivalents were found. Moreover, the meiotic chromosome behavior in the hybrid microsporogenesis was regular during synapsis, and in the distribution of chromosomes. The only exception was found in one slide in which three adjacent pollen mother cells during the first anaphase demonstrated the presence of a chromatin bridge. The observed abnormality in these three cells being apparently similar in appearance is probably

TABLE I—POLLEN MEASUREMENTS OF PARENTS AND F_1 CROSSES OF TSONTSAI WITH VARIETIES OF *B. juncea*

Parents and F_1 Hybrids	Pollen Length, μ	Difference Hybrid-Parent		Pollen Width μ	Difference Hybrid-Parent	
		(Female)	(Male)		(Female)	(Male)
Tayutsai	43.41	—	—	31.36	—	—
Tsontsai × Tayutsai	45.28	+1.87	+3.79	31.07	−0.29	+1.36
Tsontsai	41.49	—	—	29.71	—	—
Tsontsai × Shealiehontsai	41.65	+0.16	−0.88	30.46	+0.75	−1.22
Shealiehontsai	42.53	—		31.68	—	—
Significance at 5 per cent level	—	1.073		—	0.846	

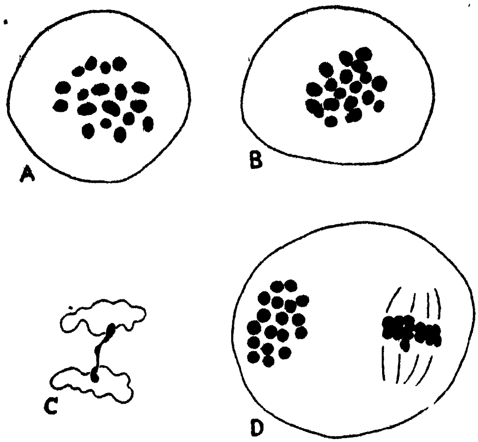

FIG. 3. A. Heterotypic metaphase of Tsontsai. B. Heterotypic metaphase of the F_1 hybrid between Tsontsai and Sheliehontsai. C. Homotypic metaphase of the F_1 hybrid between Tsontsai and Sheliehontsai. D. Heterotypic anaphase of the F_1 hybrid between Tsontsai and Sheliehontsai, where a chromatin bridge is shown.

derived from the same origin, since they not only occurred together but also looked alike especially in relation to the absence of acentric fragment. To explain the nature of this figure, two alternative explanations are suggested. Either it may be due to the heterozygosity of a short inversion situated very close to the distal end, followed by a single crossover within the inverted section, or it may be the result of the sticking together of the ends of the two homologous chromosomes. In all events, this abnormality was most probably spontaneous in origin and probably should not be considered as a real difference between the parents. The available cytological evidence does not show any great dissimilarity either in number or in gross arrangement of chromosomes between Tsontsai and Sheliehontsai.

CONCLUSION

A mutant type of *Brassica juncea,* Coss., called "Tsontsai", was found. The plant differs markedly in general appearance from other varieties of *B. juncea,* but exhibits no great difference in reproductive organs. It could be crossed without difficulty with various types of *B. juncea,* Coss. and give rise to fertile F_1 hybrid plants. Cytological studies showed that its gametic chromosome number was 18, similar to that of other varieties of *B. juncea,* and that the meiotic chromosome behavior in the Tsontsai x Sheliehontsai F_1 hybrid microsporogenesis showed a regular synapsis and distribution of chromosomes.

On the basis of the studies made, Tsontsai was classified as a variety of *Brassica juncea,* Coss. and was named *Brassica juncea,* Coss. var. *linearifolia,* Sun.

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Seasonal Variations in the Mineral and Vitamin Content of Certain Green Vegetable Crops[1]

By Elmer Hansen, *Oregon Agricultural Experiment Station, Corvallis, Ore.*

Many vegetable crops at the present time are being evaluated according to their mineral or vitamin content, and certain ones including kale and sprouting broccoli are recommended especially as sources of available calcium and other essential dietary factors (8). Although the mineral and organic composition of these crops are generally listed in food tables, only a limited amount of information is available regarding the variations that may occur within products obtained from various sources or grown under different environmental conditions. The ascorbic acid content of turnip greens has been shown to be affected by light intensity (3), and to vary according to the region where grown, as well as to the meteorological conditions prevailing during the growing season (6). The mineral content, likewise, may be greatly influenced by the composition of the soil, by weather conditions, and by other environmental factors (7). Davidson and LeClerc (2) found considerable differences in the mineral content of the same varieties of vegetables and stressed the importance of determining the range of variations rather than fixed values.

Under Western Oregon conditions, kale, sprouting broccoli and other cool-season green vegetables are planted during late summer and under favorable conditions can be harvested continually throughout the fall, winter and early spring. The present investigation was undertaken to determine the extent of variability in the calcium, phosphorus, ascorbic acid and carotene content of these crops when grown during this period.

Methods

Materials and Methods of Sampling:—Plants of sprouting broccoli, red-leaf (Rhubarb) chard, Georgia collards, dwarf Scotch kale and Prizehead lettuce were planted during July and August in 75-foot rows on Chehalis clay loam soil. A complete fertilizer (6–8–6) was applied at time of planting and portions of the rows were treated with lime, as indicated later.

Samples for analysis were harvested at approximately monthly intervals. For collards and kale, these were selected from the upper second and third whorls of leaves. For broccoli, they represented the growth from both lateral and terminal buds, and included the flower clusters with adjacent leaves and stem. Samples from chard and lettuce were selected at random from the rows. Only the younger leaves which had developed during the preceding 4 to 6 weeks' period were chosen. Prior to weighing, the materials were washed with tap and

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[1]Published as Technical Paper No. 457, with the approval of the Director, Oregon Agricultural Experiment Station. Contribution of the Department of Horticulture in a cooperative project with the Department of Home Economics.

distilled water, dried rapidly between paper towels, then cut into coarse pieces by means of a sharp knife.

Methods of Analysis:—Moisture content: Duplicate 50-gram samples were dried for 6 hours at 70 degrees C in a forced-draft oven, then to constant weight in a vacuum oven.

Total ash: The dry samples were ground through a 40-mesh screen in a semi-micro Wiley mill. After re-drying in vacuo, duplicate 1-gram samples were weighed into tared porcelain crucibles and ashed at temperatures not exceeding 600 degrees C.

Calcium and phosphorus: The micro-methods of the Association of Official Agricultural Chemists (1) were used with minor modifications. Mineral analyses of chard were not included, since the calcium is nutritionally unavailable owing to the high oxalic acid content.

Ascorbic acid: Duplicate 25-gram samples were ground for three minutes in a Waring blendor with 300 ml of 1 per cent metaphosphoric acid solution. Ascorbic acid was then determined according to the method of Morell (4) adapted for use with a Klett-Summerson colorimeter.

Carotene: Duplicate 25-gram samples were transferred to 500-ml screw-cap bottles, covered with 200 ml of 95 per cent ethanol and stored at − 15 degrees C for 24–48 hours. The samples were then transferred to the cup of a Waring blendor, using 25–30 ml of alcohol from a 50-ml graduated wash bottle. After grinding for 5 minutes, the sides of the cup were washed down with the remainder of the alcohol in the wash bottle. The suspension was then stirred with the tip of a pipette, and a 10-ml aliquot was pipetted into an Erlenmeyer flask containing 100 ml of 10 per cent alcoholic KOH solution. After refluxing for 30 minutes, the extracts were cooled and filtered through a sintered-glass filter. The separation and estimation of carotene was finally conducted according to Peterson (5).

Results and Discussion

Calcium:—According to the data (Table I, Fig. 1), calcium varied in concentration to a much greater extent than any of the other factors. In all cases calcium values (mg/100 gm of fresh material) were highest in August or September, decreased greatly during the winter, and increased to a lesser extent during the spring. In broccoli, calcium content decreased from 174 mg in September to 53 mg in December, then increased to 150 mg in April. The values for collards ranged from 436 mg in September, 101 mg in January to 174 mg in March; and in kale, from 478 mg in August, 79 mg in December to 180 mg in April. Lettuce was comparatively low in calcium throughout the season.

During the latter part of December, commercial marble lime was applied in furrows to one-half of each row of broccoli, collards and kale. The data show (Table II) that during the subsequent four months the broccoli samples from the limed plot tended to be higher in calcium than those from the untreated plot. The results obtained with the other crops were variable. The check plots in all cases greatly increased in calcium content from January to April, and it seems

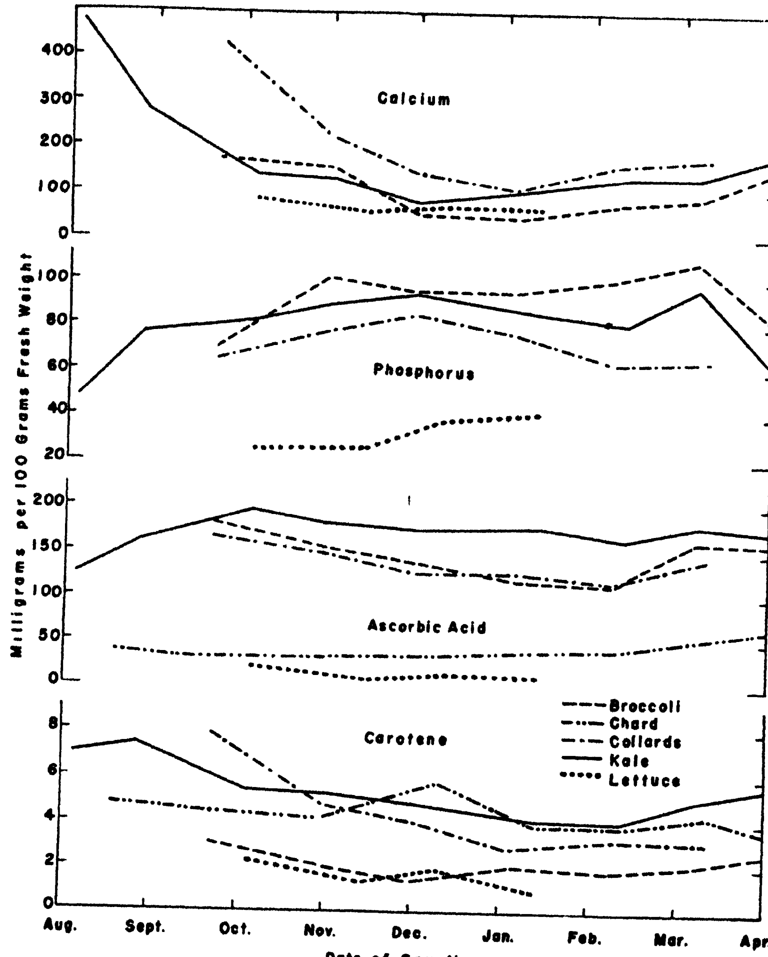

FIG. 1. Seasonal variations in the mineral and vitamin content of green vegetables.

apparent, therefore, that a deficiency of this element in the soil could not have been responsible for the low calcium levels observed during the winter months. Low prevailing temperatures (Table III) and possibly light intensity would appear to have been contributing factors.

Phosphorus:—Variations in the phosphorus content of the crops were less than those observed for calcium. The values ranged from 70 to 110 mg in broccoli, 64 to 85 mg in collards, 48 to 98 mg in kale, and 25 to 45 mg in lettuce. With certain exceptions, the samples harvested during the winter months contained more phosphorus than those harvested during either the fall or spring. This trend is opposite to that of calcium.

TABLE I—SEASONAL VARIATIONS IN THE MINERAL AND VITAMIN CONTENT OF GREEN VEGETABLES

Date of Sampling	Moisture (Per Cent)	Ash (Per Cent)	Calcium Mg/100 Gms	Phosphorus Mg/100 Gms	Ascorbic Acid Mg/100 Gms	Carotene Mg/100 Gms
			Broccoli			
Sep 21...	85.00	1.20	174.2	70.2	181.8	2.98
Nov 1 ...	86.06	1.25	152.7	100.9	153.8	1.98
Dec 1 .	87.72	0.99	53.3	95.7	137.0	1.37
Jan 3.. ..	87.70	0.91	65.5	94.6	119.8	1.97
Feb 7 ...	87.51	1.02	76.7	101.0	116.5	1.78
Mar 6 ...	85.63	1.18	87.9	109.7	161.2	2.07
Apr 3.....	86.75	1.15	149.9	80.9	159.8	2.63
			Chard			
Aug 17 .	89.16	—	—	—	34.9	4.77
Sep 9	89.59	—	—	—	30.8	4.58
Nov 1.. .	89.00	—	—	—	31.7	4.19
Dec 8....	86.00	—	—	—	33.1	5.75
Jan 12....	86.86	—	—	—	39.1	3.84
Feb 7.	87.90	—	—	—	41.4	3.80
Mar 9...	87.94	—	—	—	56.4	4.33
Apr 3. . .	88.46	—	—	—	64.3	3.66
			Collards			
Sep 21...	82.98	2.23	436.0	65.2	166.4	7.92
Nov 1 . .	84.73	1.36	221.8	78.0	145.3	4.63
Dec 1. ...	85.13	1.09	141.9	85.0	127 2	4.03
Jan 3 ...	85 44	1.06	101.2	77.0	127.2	2.86
Feb 7.. .	87.54	1.03	161.7	64.1	117 9	3.28
Mar 6 . .	85.76	1.26	173.8	65.8	142.6	3.15
			Kale			
Aug 4 .	85.83	2 28	478 1	48.2	125.7	6.89
Aug 26	83.82	1 91	285 5	77.0	159.8	7 43
Oct 4 ..	84.45	1.27	140.7	81.8	196.6	5.20
Nov 1 .	83.61	1.29	134.6	89 7	181.7	5.23
Dec 1.... .	83.08	1 14	78.5	95.2	172.8	4.84
Jan 4 . .	82.06	1.17	111.2	85.7	177.5	4.02
Feb 7 .	84.14	1.24	132 0	86.3	163.1	4.02
Mar 6 .	84 27	1.25	132.8	98.0	178.9	4.94
Apr 3....	86.17	1.36	180.1	62.8	165.8	5.50
			Lettuce			
Oct 4. ...	93.09	1.37	84.1	24.8	19.6	2.23
Nov 13 .	94 61	0.81	57.4	25.9	8.0	1.28
Dec 8 . ..	93.76	1.09	70.0	37.6	13.5	1.90
Jan 12. .	93.53	0.91	63.5	41.9	11.7	0.77

Ascorbic acid:—The ascorbic acid content of all the crops varied more or less, but no consistent seasonal trends were observed. In broccoli and collards ascorbic acid content decreased from September to February and increased during the remainder of the period. In kale there was an increase from August to October, with only minor variations occurring thereafter. Chard showed slight changes in ascorbic acid content during the fall and early winter months, but from December to April there was a consistent increase from 33 to 64 mg. Lettuce was low in ascorbic acid throughout the season. According to these data, the ascorbic acid content of a specific crop was influenced to a much greater extent by its particular hereditary constitution than by the conditions of the environment. Thus the concentration of this vitamin tended to remain high in broccoli, collards, and kale, and low in chard and lettuce, irrespective of changes in the climatic or soil conditions during the growing period.

TABLE II—EFFECT OF LIME ON CALCIUM CONTENT OF GREEN VEGETABLES

Date of Sampling	Ash		Calcium		Moisture	
	Treated	Check	Treated	Check	Treated	Check
	(Per Cent)		Mg/100 Gm		(Per Cent)	
			Broccoli			
Jan 3	0.98	0.91	72.6	65.5	86.77	87.70
Feb 7	1.02	1.02	96.0	76.7	87.98	87.51
Mar 6	1.20	1.18	108.1	87.9	85.86	85.63
Apr 3	1.24	1.15	181.7	149 9	87.73	86.75
			Collards			
Jan 3	1.03	1 06	114.2	101.2	85.70	85.44
Feb 7	1.00	1.03	148.2	161.7	87.76	87.54
Mar 6	1.34	1.26	221.5	173.8	86.34	85.76
			Kale			
Jan 4	1.18	1.17	103.3	111.2	82.00	82.06
Feb 7	1.18	1.24	122.2	132.0	83.69	84 14
Mar 6	1.26	1.25	143.3	132.8	84.49	84.27
Apr 3	1.48	1.36	200.0	180 1	86.27	86 17

TABLE III—MEAN MONTHLY TEMPERATURES DURING THE GROWING PERIOD

Month	Average Temperatures		
	Maximum	Minimum	Mean
Aug.	78.4	51 6	65.0
Sep.	81.5	50.6	66.0
Oct.	63.9	46.2	55.0
Nov	54.6	38.2	46.4
Dec.	47.3	32.5	39.9
Jan.	47.3	32.5	39.9
Feb.	52 0	35.5	43.8
Mar.	57.5	35.8	46.8

Carotene:—With the exception of chard, the concentration of carotene tended to decrease during the fall and winter and to increase to a lesser extent during the spring. The greatest variations were observed in collards, the values ranging from 7.92 mg in September, 2.86 mg in January, to 3.15 mg in March. Whether these changes are associated with available soil nitrogen, prevailing temperatures, light intensity or other variable environmental factors cannot be determined from the data available at the present time.

SUMMARY

The quantitative variations occurring in the calcium, phosphorus, ascorbic acid and carotene contents of certain green vegetables grown during the period extending from August to April have been studied.

The concentration of calcium in all the crops was highest in August or September, decreased greatly during the winter, and increased to a lesser extent during the spring. Application of lime to the soil in December had little effect on the amounts of calcium which accumulated in the plants during the remainder of the season.

Phosphorus varied less than calcium in concentration, and the values generally tended to be higher in the winter than in either the fall or spring.

The ascorbic acid content of all the crops varied to a certain extent, but no consistent seasonal trends were observed. Hereditary rather than environmental factors appeared to have been of most importance in determining ascorbic acid content.

Carotene in collards, kale and broccoli decreased considerably in concentration during the fall and increased to a lesser extent during the spring. Chard was fairly uniform in carotene content throughout the growing period.

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Growth and Yields of Cabbage, Sprouting Broccoli, and Tomato Plants Hardened by Chemicals in Nutrient Solution and Later Grown at Different Levels of Nitrogen, Phosphorus, and Potassium

By H. D. Brown, Richard Dunn and E. K. Alban, *Ohio Agricultural Experiment Station, Columbus, O.*

Southern-grown vegetable seedlings fail to meet desirable standards. Tomato seedlings are often overgrown and diseased and cabbage seedlings produce seed stalks rather than heads. Both may be so thoroughly hardened that they will start growth very slowly after they are transplanted. Home-grown seedlings are frequently no better. Theoretically, it should be possible to produce better plants where they are to be transplanted because packaging and shipping, regardless of the care exercised, are bound to injure the seedlings and reduce their value.

The study reported herein describes efforts made to harden seedlings so that they would have sufficient nitrogen within the plants to start growth as soon as they were set in the field. Plants hardened by withholding nitrogen were grown for comparison.

In 1944, sprouting broccoli, cabbage, and tomato plants grown in nutrient solution, with quartz gravel and haydite to anchor the roots, were hardened by (a) withholding nitrogen, and (b) by increasing the osmotic pressure of the nutrient solution by using K_2SO_4, and $CaCl_2$. The seedlings were then transplanted to plots, where some plants were held at high and some at low level of nitrogen, phosphorus, and potassium. The sprouting broccoli and cabbage plants were grown to maturity in the permanent fertility plots which have received the treatments indicated in Table I for 15 years. The tomato plants were set in the greenhouse water-culture plots with gravel, cinders, and haydite where a low, as well as a high, level of nitrogen, phosphorus, and potassium was maintained. The low levels of nitrogen, phosphorus, and potassium varied from 0 to 3 p p m. The highest level of nitrogen and potassium was held at 300 p p m and the highest level of phosphorus at 100 p p m. Plants were also set in plots held at medium levels of 150 p p m of nitrogen and potassium and 50 p p m of phosphorus. High and low levels of calcium, magnesium, and iron were also maintained in these plots. Calcium was maintained at approximately 100 p p m, magnesium at 25 p p m, and iron at 5 p p m, except in the low-level plots where only traces were present. Trace elements were also added to all solutions.

Unless otherwise specified, the seedlings were started at medium levels of nitrogen (150 p p m), phosphorus (50 p p m), and potassium (150 p p m). The nitrogen level was reduced to less than 5 p p m by changing the solution in one bed to harden the plants.

It required 95 pounds of K_2SO_4 in 280 gallons of solution with quartz sand to harden tomato plants. Only 49 pounds were used to harden the cabbage and sprouting broccoli in both beds, but this

amount was not adequate to produce well-hardened plants. The 95 pounds of K_2SO_4 in 280 gallons of nutrient solution in quartz sand did not harden the tomato seedlings as evenly nor as thoroughly as did the withholding of nitrogen. In addition, the plants hardened by the high osmotic values finally developed longitudinally split stems, curled leaves, and darkened roots (see Fig. 1). The roots of the nitrogen-starved plants were white and more extensive, but the leaves were yellowed, especially the older leaves. After transplanting the nitrogen-starved seedlings to rich greenhouse soil, they made a terminal growth only, whereas those seedlings hardened by high osmotic values produced new growths from buds in the axils of leaves near the base of the plant. (See Fig. 2). The soluble salt content of the minus-nitrogen bed, as measured by the electrical conductivity method, was 1500 p p m at the start and 1350 p p m when the plants were thoroughly hardened. Similarly, the K_2SO_4 plot had 1550 p p m of soluble salts at the start and 2733 p p m after the addition of 95 pounds of K_2SO_4. The osmotic pressure determined by the freezing-point depression was approximately one atmosphere for the solutions containing 1500 p p m and nine for the solution containing 2733 p p m, a value which was lower than the theoretical value. Deviations from the theoretical values may in part be explained by the accumulations of salts on the surface of the substrate, especially when the concentrated solutions were used.

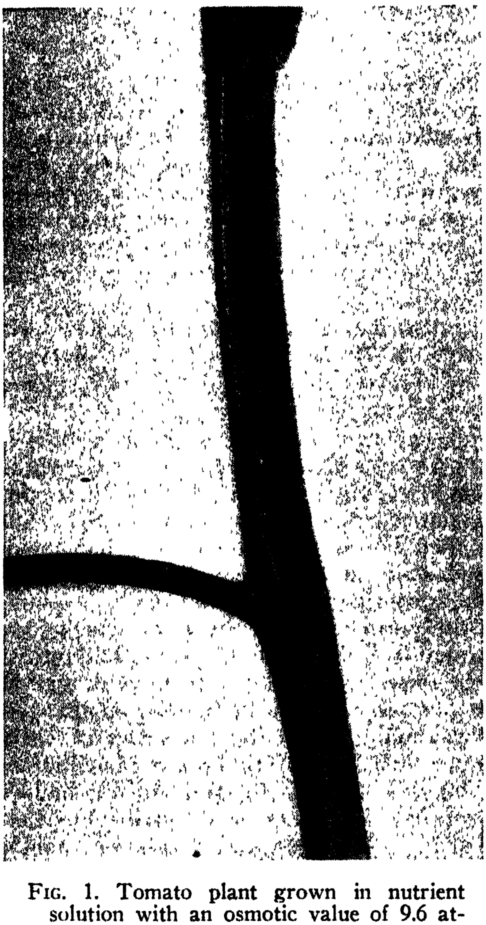

FIG. 1. Tomato plant grown in nutrient solution with an osmotic value of 9.6 atmospheres. Note longitudinal splitting.

On August 31, the sap from the well-hardened tomato plants in the minus-nitrogen bed had osmotic values of 9.21 and 9.45 (2325 p p m soluble salts) atmospheres; that from the plants hardened by additions

FIG. 2. Tomato plants hardened by withholding nitrogen (left) elongated by extension of the central axis whereas those hardened by high osmotic values (right) produced abundant growths of the axillary shoots.

of K_2SO_4 had values of 20.4 and 20.6 atmospheres (5268 p p m soluble salts). Sap from potted plants tested as checks had values of 9.7 and 9.6 atmospheres (2667 p p m soluble salts). All osmotic determinations were made by the freezing point-depression method. It is obvious from these data that the osmotic values of plants hardened by withholding nitrogen are not higher than those of unhardened plants.

Tomato plants grown in May and June were set in the fertility plots in the greenhouse on June 22. At this time, there were 36 treatments in all (See third paragraph). Only 12, or 33⅓ per cent, of the plants survived which were hardened by withholding nitrogen, and on July 27 these had grown to an average height of 7.3 inches. Twenty-three, or 63.9 per cent, of the plants survived which were hardened by K_2SO_4 and they had an average height of 6.6 inches. Twenty-five, or 69.4 per cent of the plants survived which were hardened with $CaCl_2$. The average height on July 27 was 9.2 inches. The low percentage of survival may be attributed in part to the extremely hot weather at transplanting time and to the fact that no soil, haydite, or gravel was transferred with the roots at transplanting time. For this reason, no attempt was made to evaluate growth responses at different fertility levels.

The sprouting broccoli and cabbage plants were set in the fertility plots in the field June 1. At this time, the plants grown in the minus-

nitrogen plots were well hardened and they stood the shock of transplanting much better that the plants which were only partially hardened by $CaCl_2$ and K_2SO_4. With adequate irrigation, however, the two latter lots quickly overcame this early setback and outyielded the plants hardened by nitrogen starvation. The yields for sprouting broccoli are shown in Table I.

TABLE I—SPROUTING BROCCOLI YIELD, COLUMBUS, OHIO, 1944

Fertilizer (1000 Pounds per Acre)	Average Weight (Pounds Per Plant)					
	Hardened by Withholding N		Hardened by Addition of K_2SO_4		Hardened by Addition of $CaCl_2$	
	Prior to Jul 15	Total to Sep 1	Prior to Jul 15	Total to Sep 1	Prior to Jul 15	Total to Sep 1
No fertilizer	0.00	0.27	0.21	0.59	0.17	0.73
0-20-12	0.05	0.31	0.28	0.60	0.19	0.48
8- 0-12	0.19	0.63	0 19	0.63	0.23	0.54
8-20- 0	0.08	0.50	0 20	0.61	0.27	0.76
8-20 12	0 22	0.65	0.32	0.90	0.23	0.70
16-20-12	0 12	0.68	0.53	1.00	0.34	1.05
8-40-12	0.13	0.58	0.29	0.85	0.27	0.73
8-20-24	0.08	0.70	0.32	0.69	0.35	1.00
Average	0.11	0.54	0.29	0.73	0.26	0.75

Needed for significant difference: 0.075 pound for July 15th yields.
No significant difference by analyses of variance for total to Sep 1st yields.
Average of 33 plants per treatment.

The July 15th yields of the plants hardened by increasing the osmostic values of the nutrient solutions are significantly (1 per cent level) higher than the yields of the plants hardened by withholding nitrogen if the same levels of soil fertility are compared. It is also obvious from the data that the high nitrogen content of the plants hardened by high osmotic values is not adequate to overcome the lack of nitrogen in the minus-nitrogen plots. In view of the peculiar growth effects of high osmotic concentrations, this method cannot be recommended at present.

The data for cabbage are shown in table II. Although the trend is the same as for broccoli, no significant differences were secured.

TABLE II—CABBAGE YIELDS, COLUMBUS, OHIO, 1944

Fertilizer (1000 Pounds per Acre)	Average Weight (Pounds per Plant)		
	Hardened by Withholding Nitrogen	Hardened by Addition of K_2SO_4	Hardened by Addition of $CaCl_2$
No fertilizer	1.4	2.1	2.9
0-20-12	2.0	2.3	2.6
8- 0-12	2.0	3.1	2.9
8-20- 0	3.1	3 0	2.8
8-20-12	2.5	2.6	2.8
16-20-12	2.6	2.0	2.7
8-40-12	2.4	2.9	3.2
8-20-24	2.2	3.3	2.7
Average	2.3	2.7	2.8

The Influence of Soil pH and Organic Matter Upon the Yields of Some Vegetable Crops

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IN studies of the effects of various soil factors upon yields of vegetable crops it was found that, with the exception of moisture, crop yields under an intensive system of cultivation were more often limited by either undesirable soil pH or organic matter than by any other soil factor. When both pH and organic matter of the soil were considered, the presence of optimum ranges was an insurance of good crops under a wide range of conditions. Inadequate soil pH combined with inadequate organic matter was an indication of crop failure unless all other conditions including soil moisture were optimum or nearly so.

The benefits of proper liming and the presence of sufficient organic matter have been known since ancient times. It is surprising, therefore, to note the large acreage that is being farmed in many sections under rather intensive conditions without proper attention to soil pH and organic matter content. Our studies would indicate that such attention is absolutely necessary and the presence of an adequate pH and sufficient organic matter is a prime requisite before planting many vegetable crops. These studies are briefly presented in order that importance of these factors may be stressed.

A brief discussion as to the methods of the study may be of value. The studies were conducted in South Jersey. The majority of samples and yield data came from Seabrook Farms, the remainder from nearby farmers. Several important vegetable crops (Henderson lima beans, peas, tomatoes, and spinach) were used. Results from approximately 5000 acres of Henderson lima beans, 2000 acres of peas, 1500 acres of spinach, and 300 acres of tomatoes are represented in each year's studies.

The fertilizers applied per acre for the various crops were: about 1000 pounds of 4–12–8 for the beans unless they followed peas (in such cases no fertilizer was applied, the bean crop depending upon the residual fertilizer of peas); from 1500 to 2000 pounds 4–12–8 for peas; about 1500 pounds 4–12–8 plus 400 pounds cyanamid and 300 pounds of nitrate of soda for spinach. The fertilizer for tomatoes varied greatly with individual farmers but in many cases approximated 1000 to 1500 pounds of a 5–10–10 per acre.

The soils on which the crops were grown were of Coastal Plain origin and consisted primarily of the Sassafras and Collington series. The types of soil represented were sandy loam, gravelly loam, loam, and silt loam, with the majority being either sandy loam or loam.

In collecting samples, about eight borings of the plowed soil were composited into a single sample. A sample represented five acres or less of soil.

Measurements of pH were made by glass electrode using a 1:1 water to soil suspension which had been standing for at least 1 hour.

Organic matter was determined by a rapid method using a sulfuric acid-dichromate mixture to oxidize organic matter and ferrous ammonium sulfate to titrate the excess dichromate present.

In preliminary studies, it had been found that the amounts of organic matter in a soil could be closely correlated with the yields. This relationship was more striking in a season of abnormally dry or abnormally wet weather than in one of optimum moisture conditions. Also, the importance of organic matter was greater in fields not receiving any irrigation.

In general, fields containing less than 1 per cent organic matter gave poor yields or in some cases complete crop failure. Those fields having between 1 and 1.5 per cent of organic matter produced fair crops. If there was more than 1.5 per cent organic matter, fields produced good crops in nearly all cases and there were no instances of complete crop failures.

The above three categories have been listed as poor, fair, and good, and were so used in the studies. It is understood that the divisions are rather arbitrary and are dependent in part upon the quality of organic matter present. It is also realized that the amounts of organic matter that would designate a soil as being poor, fair, or good would vary with different soil. However, the divisions have been found practical for these Coastal Plain soils.

The pH value of a soil also influenced the yield of crop produced, the extent of influence depending upon the crop and several other soil factors. In our studies, pH values of less than 5.5 have been poor for all crops studied. However, while soils with pH values of less than 5.5 still produced appreciable crops of beans, their production of spinach was very meagre. A pH value of 5.5 to 6.0 has been fair and values of 6.0 to 6.5 have been good for these crops.

Values above 6.5 have been associated with various yields. In some

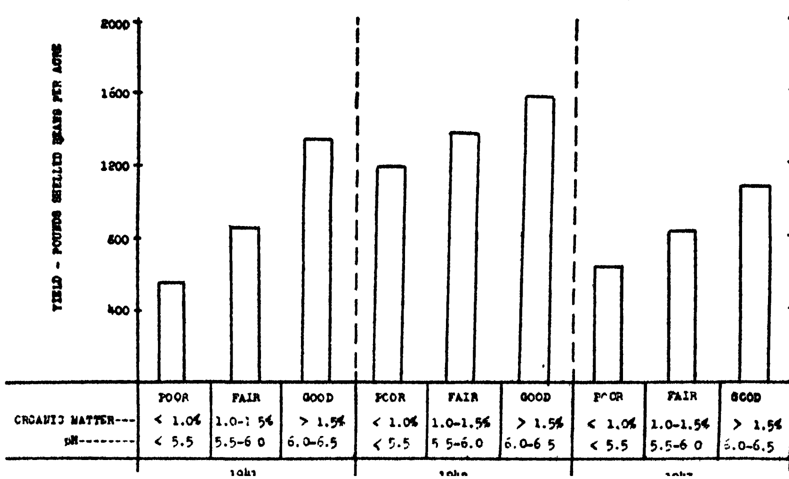

Fig. 1. The influence of soil organic matter and pH upon yields of Henderson lima beans.

fields these high pH values have been satisfactory but in many others, especially if the organic matter content was low, yields have been depressed. Evidently certain elements may have become unavailable for crop growth at such high pH values.

The importance of either pH value or organic matter singly has been modified by the relative presence of the other. For example, a soil pH value of 5.5 was more harmful when the organic matter content was poor than when at optimum level. The organic matter was capable of supplying buffer capacity to partially nullify the effects of pH. Conversely, the full effects of organic matter were not obtained unless there was a sufficiently high pH to favor chemical and biological activity capable of utilizing the organic matter to full advantage.

The effects of pH and organic matter combined are illustrated in Figs. 1–4.

The general effects of these factors are conclusive evidence of their importance in production of these vegetable crops. It is natural that the effects should vary with the particular crop and the same crop for different seasons. The type of crop and the weather will decide the

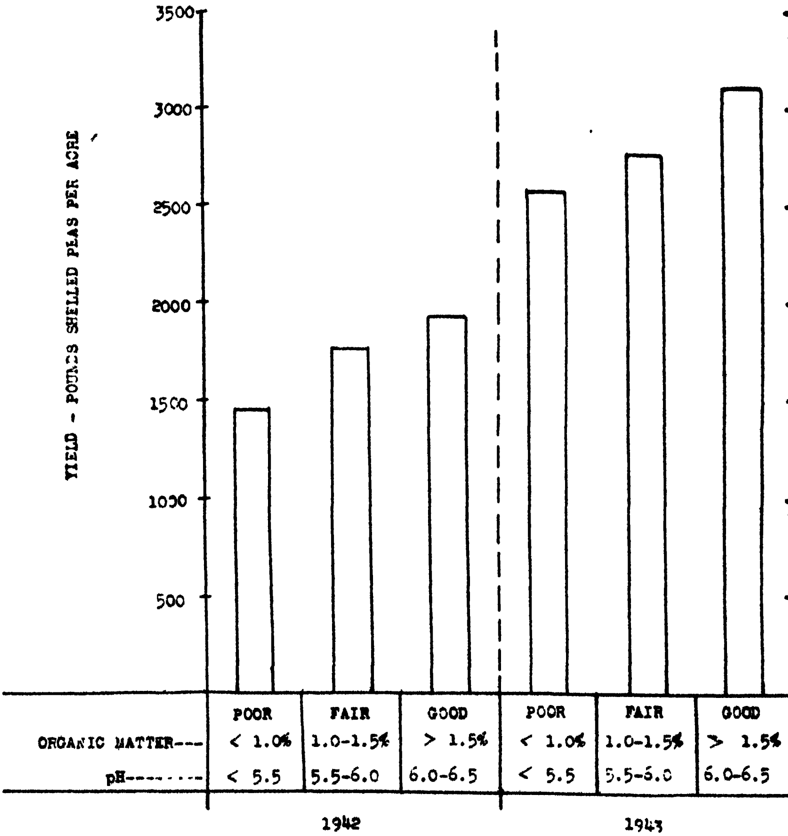

FIG. 2. The influence of soil organic matter and pH upon yields of peas.

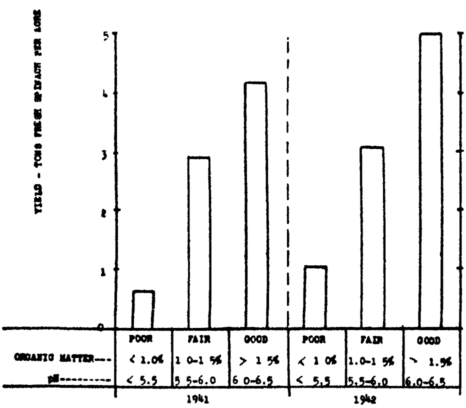

FIG. 3. The influence of soil organic matter and pH upon yields of spinach.

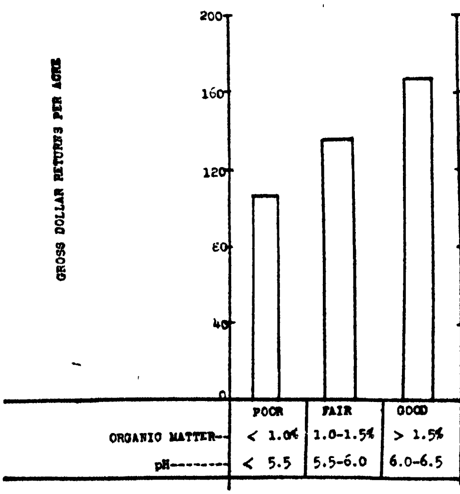

FIG. 4. The influence of soil organic matter and pH upon gross dollar returns per acre of tomatoes in 1942.

extent of response to these factors. Witness, for example, the 133 per cent increase of bean yields in 1941 on soils having good pH and organic matter as compared to soils poor in these factors. The increase for 1942, a more favorable year as far as moisture was concerned, was only 33 per cent. Also, the yields of spinach on soils good in these factors were approximately five times as great as on soils low in pH and organic matter.

The response to these factors points to the general importance in a program of vegetable growing. It is indicated that proper soil pH value and sufficient organic matter ought to be a prerequisite for successful vegetable intensive farming.

The variations in yield with crops receiving the same amount of fertilizers indicate that full advantage is not taken of the fertilizer unless sufficient organic matter and a sufficiently high pH is present. The increases in yields due to higher organic matter and pH values are due in part to the increase of soluble nutrients released from organic matter or lime or from the soil because of changes in solubility. Some of these increases are a result of changes in the physical structure of the soil allowing better conservation of moisture and soil with a resultant improvement of aeration. Not the least effect, however, is maintenance in soluble forms of fertilizers applied and a better absorption of nutrients by plants when sufficient organic matter and lime are present.

Some farmers, intentionally or otherwise, have tried to substitute

large applications of commercial fertilizers for deficiencies of pH or organic matter. Such a practice, at least temporarily, may tend to keep up crop yields. However, it is not as satisfactory as using enough lime and organic matter and sufficient fertilizer for the crop needs. The system of using large amounts of fertilizer to make up for lower pH and organic matter values is unsatisfactory for several reasons. Invariably, as the organic matter drops, larger amounts of fertilizer will be needed. Eventually, the amounts of fertilizer used may cause serious difficulty because of the temporary presence of toxic concentrations of salts. Also, while some of the elements may be supplied, there is usually a shortage of calcium or magnesium or both. The physical effects of both organic matter and lime are not readily obtained by other means and this evidently is as important as the chemical aspects. Finally, it is much cheaper to supply sufficient lime and organic matter and after these have been applied to supply the necessary fertilizer ingredients.

In conclusion, studies have shown that crop yields of Henderson lima beans, peas, spinach and tomatoes are correlated with soil pH and organic matter. The importance of these soil factors will vary with different crops and with the same crop in different seasons. Our results would indicate that an organic matter content of at least 1.5 per cent and a soil pH of 6.0 to 6.5 was most satisfactory for these crops. Unless these factors are optimum or nearly so, the fertilizers applied are not fully utilized. Larger applications of fertilizers to overcome deficiencies of either or both of these factors are only partially successful. Proper attention to soil organic matter and pH, therefore, should be one of the first requisites in preparing a soil for these vegetable crops.

The Influence of Nitrogen Nutrition Upon the Ascorbic Acid Content of Several Vegetable Crops

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In connection with physiological studies of citrus, especially grapefruit (1), it was found that under the climatic conditions of Arizona the concentration of ascorbic acid in the juice bore a marked inverse relation to the nitrogen value. This latter, in turn, reflected the plane of nitrogen nutrition of the tree during the time the fruit grew and developed as influenced by nitrogen fertilization and other cultural practices. In view of these results, it was decided to conduct similar studies with vegetables to ascertain if such a relationship would hold for them and thus to learn if there might be a possibility of increasing the vitamin C content of these crops through proper adjustment of fertilization and cultural practices.

Experimental Procedure and Data

Cantaloup:—Arizona No. 13 cantaloups were planted on the Yuma Mesa, February 16, 1944, in three 100-foot rows. The rows were planted at the side of an irrigation furrow and were separated by a large raised bed seven feet wide. The soil on the Yuma Mesa is composed of more than 90 per cent sand so that there is no appreciable lateral movement of the water or, in this case, of nitrogen fertilizer from one row to another. On the other hand, the rapid downward movement of water permitted leaching of nitrates below the root zone where a low plane of nitrogen nutrition was desired. Phosphates were applied below the seed to all rows at planting time. Ammonium sulfate was applied occasionally, by dissolving in irrigation water, to all plots during the early growth of the plants and continuing up to the time of fruit setting. When the "crown set" fruit were about one inch in diameter, differential treatments were initiated to induce differences in the nitrogen content of the plants during the period of fruit growth and ripening. The culture from fruit setting-on was as follows:

Row 1—Beginning May 10, 1944, ½ pound of ammonium sulfate was applied each week. In addition, a layer of cheesecloth was stretched horizontally on a framework about three feet above the vines. This reduced the intensity of the light striking the leaves from the usual 10,000–12,000 to about 6,000 foot candles.

Row 2—One-half pound of ammonium sulfate was applied each week.

Row 3—No fertilizer was applied and since liberal irrigations were made three times weekly, nitrogen was for the most part washed below the root zone and plants of this plot were deprived of nitrogen during the period of fruit growth and ripening.

That the above treatments induced differences in the nitrogen level

[1]The writers are indebted to Mr. Edmund C. Currlin who grew the cantaloups at Yuma and to Mr. Steve Fazio who grew the other plants studied.

of the plants was shown by analyses of the leaves made during the period of fruit harvest. For these analyses the youngest fully expanded leaf on 100 runners was collected on seven different dates between June 6 and June 29. The nitrogen values for all seven collections were uniform for each plot throughout this period. The average percentage nitrogen found in the leaves was: Row 1, 3.64; Row 2, 2.86; and Row 3, 1.97. Obviously the fruit matured under different conditions of nitrogen nutrition of the plant.

Fruit was harvested as soon as it attained the "full slip" stage. It was harvested one day, shipped to Tucson that night and analyses begun the next day. There were seven sampling dates from June 12 to 29, inclusive, and a total of 80 individual fruits were analyzed. Nitrogen was determined by the micro method (2) and ascorbic acid by visual titration with dichlorobenzenoneindophenol of a macerated sample of the edible portion taken up with meta phosphoric acid.

The average nitrogen and ascorbic acid values for all fruit from the three plots are shown in Table I.

TABLE I—ASCORBIC ACID AND NITROGEN IN EDIBLE PORTION OF CANTALOUP. EXPRESSED AS MG/100 GM FRESH MATERIAL

Material	Row 1—(Ave 29 Fruit)	Row 2—(Ave 27 Fruit)	Row 3—(Ave 24 Fruit)
Ascorbic acid	46.6	54.9	61.4
Nitrogen	130.9	111.5	83.6

A better comparison of the data of Table I can perhaps be obtained by showing the percentage increase in ascorbic acid associated with a decrease in nitrogen content. This is done in Table II where the nitrogen and ascorbic acid values of Row 1 are taken as 100 per cent. This treatment of the data is appropriate since the vitamin C value in Row 1 (46.6 mg/100 gm) is approximately that found for this variety when grown in heavier soils under commercial handling. As indicated in Table II, a substantial percentage increase in ascorbic acid was associated with a decrease in nitrogen.

TABLE II—RELATION OF NITROGEN TO ASCORBIC ACID IN CANTALOUPS WHERE THE VALUES OF ROW 1 ARE TAKEN AS 100 PER CENT

Material	Nitrogen	Ascorbic Acid
Row 1	100.0	100.0
Row 2	85.2	117.8
Row 3	63.9	131.8

As already indicated, a total of 80 fruit were analyzed individually. A negative correlation of 0.55 is obtained between ascorbic acid and nitrogen when the values for each fruit are considered without regard to row or date of collection.

Potato:—Studies on potatoes followed the general pattern of that for cantaloups. The potatoes were grown on a soil of medium texture at Tucson. There was not the opportunity of leaching nitrogen below

the root zone as there was with the cantaloups on the sandy Yuma Mesa soil.

Three varieties were used, namely, Bliss Triumph, White Rose and Katahdin. These were planted on March 22, 1944. Phosphates were applied under the seed at planting. On May 2, ammonium sulfate was applied to all plots at the rate of about 100 pounds per acre. Tuberization was well started by the middle of May. At this time the cheesecloth shade was placed over one plot and from that time until harvest the handling was comparable to that described above for cantaloups.

Using technique as for cantaloups a sample of leaves was obtained from the Bliss Triumph variety just prior to harvest. Both nitrogen and ascorbic acid were determined on these leaves. The amounts found are shown in Table III.

TABLE III—NITROGEN AND ASCORBIC ACID CONTENT OF BLISS TRIUMPH LEAVES FROM THE DIFFERENT PLOTS*

Treatment During Tuber Forming Period

No Nitrogen Application		Frequent Nitrogen Application		Shade With Frequent Nitrogen Application	
Nitrogen	Ascorbic Acid	Nitrogen	Ascorbic Acid	Nitrogen	Ascorbic Acid
2.58	95.50	4.21	90.15	4.43	66.34

*Ascorbic acid expressed as mg/100 gm fresh weight and nitrogen as percentage dry weight.

It would appear that the treatments induced differences in nitrogen values of the leaves of this variety and that these were associated inversely with the ascorbic acid content of the same tissue.

The tubers were dug on July 10, 1944, and analyzed promptly. The results are shown in Table IV.

TABLE IV—NITROGEN AND ASCORBIC ACID IN POTATO TUBERS*. HARVESTED JULY 10, 1944

Treatment During Period of Tuber Formation

	No Nitrogen Application		Frequent Nitrogen Application		Shade With Frequent Nitrogen Application	
	Nitrogen	Ascorbic Acid	Nitrogen	Ascorbic Acid	Nitrogen	Ascorbic Acid
Bliss Triumph	1.41	50.3	1.81	37.8	1.81	37.6
White Rose	0.91	37.7	1.27	35.9	1.41	27.1
Katahdin	1.35	39.9	1.88	29.5	1.86	24.7

*Ascorbic acid expressed as mg/100 gm fresh weight and nitrogen as percentage dry weight.

The data of Table IV again reveal an inverse relation of nitrogen to ascorbic acid. An effect of light is also possibly indicated. In the case of the Bliss Triumph, tubers having the highest Vitamin C content were produced where no nitrogen was applied during the tuber forming period. Here the nitrogen content was the lowest. Nitrogen was increased to the same level in the other two plots and

ascorbic acid was decreased to a uniform level. In the case of the White Rose, nitrogen increased with treatment and ascorbic acid decreased. In the case of the Katahdin, the lowest nitrogen and the highest ascorbic acid values occurred when nitrogen fertilization was withheld. But, as in the case of the Bliss Triumph, the addition of shade did not increase nitrogen in the tubers. Here the further reduction in ascorbic acid value could possibly be a direct effect of reduced light intensity. The possible interaction of light and nitrogen in influencing ascorbic acid values has been discussed elsewhere (1).

Puncture Vine (Tribulus terrestris):—In connection with the potato study, an interesting opportunity occurred to obtain data on ascorbic acid/nitrogen relationships as revealed in this common weed of the desert southwest. No labor for weeding was available during the later stages of growth of the potatoes and this low prostrate weed grew abundantly in all plots. The character of its growth in the different plots suggested at once that it had responded to the different treatments. On July 6, when the Bliss Triumph leaves were collected, similar samples of puncture vine leaves were obtained. Results of the analyses of these are shown in Table V. It is apparent that the nitrogen content of the leaves of this plant was influenced by the treatment and that the ascorbic acid value of the leaves bore an inverse relation to the nitrogen.

TABLE V—NITROGEN AND ASCORBIC ACID IN LEAVES OF PUNCTURE VINE*

Treatment During Growth					
No Nitrogen Application		Frequent Nitrogen Application		Shade With Frequent Nitrogen Application	
Nitrogen	Ascorbic Acid	Nitrogen	Ascorbic Acid	Nitrogen	Ascorbic Acid
2.41	137 50	4.47	131.08	4.73	116.63

*Ascorbic acid expressed as mg/100 gm fresh weight and nitrogen as percentage dry weight.

Green Pepper:—One row of California Wonder peppers growing in the Horticultural garden during the summer of 1944 afforded opportunity to extend observations on nitrogen and ascorbic acid relationships to this crop which is known to contain large amounts of vitamin C. When the plants were about half-grown and setting fruit, one-half of the row was fertilized with ammonium sulfate and given several subsequent applications. The other half of the row received no fertilizer during the perior of fruit development. Only one sample of fruit was analyzed. This gave the data shown in Table VI.

TABLE VI—NITROGEN AND ASCORBIC ACID IN GREEN PEPPERS

Treatment	Nitrogen (Percentage Dry Weight)	Ascorbic Acid (mg/100 gm Fresh Material)
Not fertilized	1.44	153.2
Fertilized	1.87	146.3

Summary and Discussion

The data presented herewith are believed to support that presented for grapefruit (1) in which an inverse nitrogen-ascorbic acid relation was found. It is not implied that such a relation may always hold for all climatic conditions, since as was pointed out in reporting the data on grapefruit, the amount of ascorbic acid in the plant is believed to represent the difference between that synthesized and that utilized. But in the arid southwest where light intensities are high and apparently ample for photosynthesis, nitrogen appears to exert an important regulating effect upon the ascorbic acid content of the fruit or vegetable.

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Effects of Fertilizers, Animal Manures and Green Manures on the Yield of Vegetable Crops on Light Garden Soils

By L. M. WARE and W. A. JOHNSON, *University of Alabama, Auburn, Ala.*

THE soils of the South are characteristically low in organic matter. This is especially true of some of the loamy sands and lighter soils. On these soils many vegetables sensitive to soil conditions fail almost completely without the addition of organic matter. Furthermore, there is a great difference in the effects of animal manures and green manures and a great difference in the effects of green manures turned at different seasons.

Studies have been conducted for a number of years at the Alabama Agricultural Experiment Station in which the effects on vegetable crops of fertilizers, of animal manures, and of green manures turned at different seasons have been measured. The experiments now in the sixth year were conducted on composited soils in cement bins. Treatments were quadrupled and the vegetable crops were rotated.

A sufficient number of records is presented to indicate the general trend of the results.

RESULTS

Effects of Fertilizers and Animal Manures on Vegetable Yields:—The yields of four vegetable crops fertilized at different rates and supplied animal manures are given in Table I. No increase in yield resulted from an increase in application of fertilizers from 1,000 to 1,500 pounds per acre; however, at the lower rate of fertilizer application, 12 tons per acre of manures almost doubled the yield of lettuce and cabbage and increased the yields of beets seven times and the yields of carrots two and one-half times. Yields of lettuce, carrots, and beets were very low without manure even though they received high rates of commercial fertilizers.

TABLE I—YIELD OF VEGETABLE CROPS FOLLOWING APPLICATIONS OF ANIMAL MANURES AND DIFFERENT RATES OF FERTILIZERS

Fertilizer Added (Pounds of 6–10–6)	Manure Added	Yield of Crops (Pounds per Acre)			
		Lettuce	Beets	Carrots	Cabbage
1,000	None	3,475	736	4,462	7,516
1,000	Animal	6,676	5,387	11,085	12,851
1,500	None	2,919	1,170	3,005	5,875

Comparative Effects of Animal Manures and Green Manures on Yield:—The yields of tomatoes and sweet corn following vetch and rye and following applications of animal manures are given in Table II. The yields of tomatoes were increased approximately one-third by turning either vetch or rye and were almost doubled by an appli-

cation of animal manure. No increases in yield resulted by turning vetch in addition to adding animal manures. The addition of manure to plots receiving vetch increased the yield of tomatoes 50 per cent. Vetch and animal manures each increased the yield of sweet corn about three times; a small increase resulted from the use of both.

TABLE II—YIELD OF VEGETABLE CROPS FOLLOWING APPLICATIONS OF ANIMAL AND GREEN MANURES

Fertilizer Added (Pounds of 6-10-6)	Manures Added		Yield per Acre	
	Animal	Green	Tomatoes (Bushels)	Sweet Corn (Pounds)
1,000	—	—	369	2,281
1,000	Manure	—	709	8,176
1,000	----	Rye	460	4,810
1,000	—	Vetch	467	7,395
1,000	Manure	Vetch	697	9,114

Value of Winter Legumes for Summer Vegetables:—The yields of snap beans and lima beans with and without commercial nitrogen added to plots receiving and not receiving winter legumes are given in Table III. The yield of snap beans was increased from 3 to 161 bushels per acre as a result of turning vetch when no commercial nitrogen was added and was increased from 144 to 226 bushels when nitrogen was added. The yield of lima beans without commercial nitrogen and without a winter legume was 70 bushels per acre; the yield was increased to 270 bushels by the turning of vetch. Commercial nitrogen after a legume had been turned increased the yield of lima beans from 270 to 323 bushels per acre. Legumes increased the yield of eggplants over four times, 60 pounds of nitrogen increased the yield three times, and a combination of the two increased the yield six times.

TABLE III—YIELD OF SUMMER VEGETABLE CROPS FOLLOWING WINTER LEGUMES

Fertilizer (1,000 Pounds per Acre)	Winter Legune Turned	Yield per Acre		
		Snap Beans (Bushels)	Lima Beans (Bushels)	Eggplants (Pounds)
0-10-6	0	3	70	7,903
0-10-6	Vetch	161	270	36,292
6-10-6	0	144	242	25,576
6-10-6	Vetch	226	323	48,110

Value of Winter Legumes for Fall Vegetables:—Data in Table IV indicate that winter legumes may exert a considerable influence on vegetable crops the following fall, even though an intervening summer vegetable crop has been grown. The effects are especially noticeable where no nitrogen has been added to the vegetable crop; however, legumes did not give yields as high as 60 pounds per acre of nitrogen. Yields were increased by use of both legumes and nitrogen over either used alone.

TABLE IV—YIELD OF FALL VEGETABLE CROPS FOLLOWING WINTER LEGUMES

Fertilizer (1,000 Pounds Per Acre)	Winter Legume Turned	Yields per Acre (Pounds)		
		Turnips	Chinese Cabbage	Tendergreen
0-10-6	—	217	1,447	960
0-10-6	Vetch	4,922	7,628	5,658
6-10-6	—	7,409	13,248	10,112
6-10-6	Vetch	10,676	18,797	13,440

Effects of Summer Legumes on Fall Vegetable Crops:—Summer legumes exerted a pronounced influence on the yield of fall vegetables where no nitrogen was added; however, the yields were higher from nitrogen applications than from legumes, and no increase in yield resulted from the use of both legumes and nitrogen. Results were with cole crops only, and these crops are not very sensitive to soil conditions. The results are given in Table V.

TABLE V—YIELD OF FALL VEGETABLE CROPS FOLLOWING SUMMER LEGUMES

Fertilizer (1,000 Pounds Per Acre)	Summer Legume Turned	Yields per Acre (Pounds)		
		Turnips (Roots)	Chinese Cabbage	Tendergreen
0-10-6	—	2,772	4,212	3,187
0-10-6	Cowpeas	17,145	21,850	13,581
6-10-6	—	31,624	36,915	28,813
6-10-6	Cowpeas	29,050	38,989	28,979

Effects of summer legumes on the yield of spring vegetable crops the following year are limited. The low temperatures prevailing from February to May are not conducive to rapid nitrate formation. Heavy rains leach out such nitrates as may be formed. Results are given on four crops in Table VI.

TABLE VI—YIELD OF SPRING VEGETABLES FOLLOWING SUMMER LEGUMES OF THE PREVIOUS YEAR

Fertilizer (1,000 Pounds per Acre)	Summer Legume Turned	Yield of Vegetables (Pounds)			
		Beets	Carrots	Cabbage	Lettuce
0-10-6	None	557	226	0	77
0-10-6	Cowpeas	1,830	1,083	256	499
6-10-6	None	5,870	3,059	12,666	9,830
6-10-6	Cowpeas	6,387	3,563	14,765	12,679

Effects of Summer Legumes on Summer Vegetable Crops:—The effects of summer legumes on summer vegetable crops the following year are about the same as on spring crops. Results with tomatoes are given in Table VII.

TABLE VII—Yield of Early Summer Vegetable Crops Following Late Summer Legumes of the Previous Year

Fertilizer (1,000 Pounds Per Acre)	Summer Legumes Turned	Yield Per Acre (Bushels) Beans
0-10-6		69.1
0-10-6	Cowpeas	110.7
6-10-6	—	436.2
6-10-6	Cowpeas	490.5

Summary and Conclusions

Results of a number of years of experimental studies in cement bins on light garden soils have shown the following:

1. The addition of organic matter results in increased yields of vegetable crops.
2. Very low yields of lettuce, beets, and carrots are obtained when not supplied animal manures; members of the cole family have not been so sensitive.
3. Animal manures exert a greater effect on vegetable yields than do green manures.
4. Winter legumes exert a pronounced effect on the yield of summer vegetable crops and a measurable effect on fall vegetable crops following the summer vegetables.
5. Summer legumes exert a pronounced effect on the yield of fall vegetables with only limited effect on spring and summer vegetables the following year.

Some Notes on the Mechanics of Applying Selective Herbicides to Vegetable Crops[1]

By WILLIAM H. LACHMAN, *Massachusetts State College, Amherst, Mass.*

A GREAT deal of interest has been shown recently in the development and use of selective herbicides for vegetable crops. Much of this work is in the advanced experimental phase and some of these developments have found widespread use with vegetable growers. The use of Sinox for weed control in onions, garlic, peas and sweet corn (2, 4, 11, 12, 14) has gained considerable interest in many areas. Dilute sulphuric acid for weed control in onions (1, 4, 8, 12) has given much promise as a means of economically and effectively eliminating the very costly hand weeding which is generally attendant on the culture of onions. Oil sprays for weed control in carrots, parsnips, parsley, celery and other members of the family Umbelliferae (3, 4, 5, 6, 7, 9, 12, 13) are especially promising in the battle on weeds. As might be expected, most of the work has been focused on the search for herbicides while only a few investigators (10, 12) have been concerned with the development of equipment and suitable methods for applying such herbicides to weeds.

Raynor (10) and Robbins *et al* (12) have made rather exhaustive studies of equipment and methods for applying weed killers. It is the intention of this paper to supplement their work with a few pertinent problems that have been encountered and to reemphasize some points for those who contemplate work in this field.

A knapsack sprayer with a diaphragm-pump is perhaps the best sprayer to use for experimental work when equipped with the proper nozzle. This type sprayer may also be used to good advantage on areas up to one acre in size. The use of knapsack sprayers is not practical on fields larger than this since it generally will be more economical to use a power sprayer.

Almost any type power rig for applying insecticides and fungicides may be easily adapted to spraying weeds but this usually entails the construction of a suitable boom fitted with special nozzles. A good spray rig can be made by attaching the boom to the front of a small truck while the pump and tank are carried in the body. With a trailer arrangement it is necessary to syncronize the wheel alignments of trailer and tractor in order to reduce crop damage. When purchasing a sprayer, the pump is generally conceded to be the most important part of the equipment and although high pressures are not a requisite for spraying weeds (usually not over 100 pounds), the capacity of the pump should be ample. This, of course, is dependent on the length of the boom and the orifice size of the nozzles.

As indicated above, relatively low pressures (not below 50 pounds) suffice for weed control since a coarse spray or mild drench is more desirable than the drifting mist that is developed by high pressures.

A shut-off valve should be placed near the tractor driver so that

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[1]Massachusetts Agricultural Experiment Station Contribution No. 564.

he may control the delivery of the herbicide as desired. Although an agitator may not be needed for the herbicides now being used, the possibility of using emulsions for weed control would make an agitator an essential part of the sprayer.

The rubber and fabric plunger cups in the pump will very likely need to be replaced more often than usual where oils are used as herbicides because certain oils have a solvent action on the rubber. The use of synthetic rubber or other suitable material in plunger cups may be possible but in any case it is desirable to clean out the sprayer with strong soap or dairy cleanser after using oil sprays.

The boom illustrated in Fig. 1 was made from three-quarter inch pipe. One-inch pipe would probably be necessary for a large boom where high capacity and greater rigidity are needed.

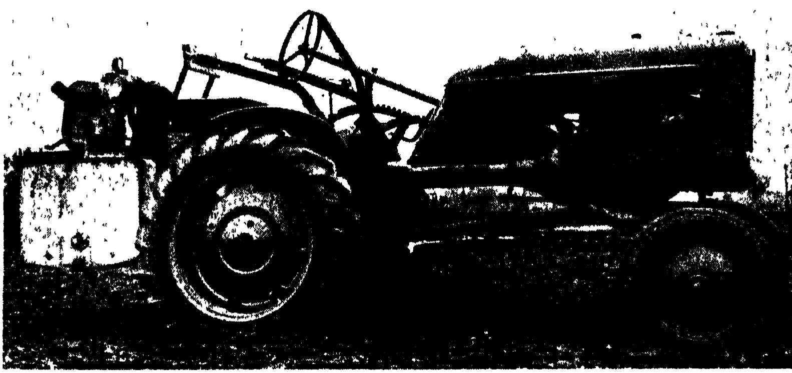

FIG. 1. A sprayer rig for demonstrational and small scale commercial application of oil spray to carrots and parsnips. The tank has a capacity of 50 gallons and will spray one-half an acre without refilling.

The boom may be drilled and tapped directly or it may take the form of a series of nipples and reducing T's into which the nozzles may be fitted. The length of the boom is dependent upon the number and spacing of the nozzles and also the topography of the land. The length of the boom is also limited by the capacity of the pump since the pump will supply only a given number of nozzles at a certain pressure.

When spraying row crops, one nozzle should be placed over each row and the boom must be carried at a height so that the edges of the spray fans meet halfway between the crop rows. Where rows are close together it may be possible to spray two rows with each nozzle. For practical purposes the boom should be carried at a height between 8 and 30 inches. When carried much higher than this the wind often interferes with proper delivery of the spray so that the best coverage and penetration are not attained. If the boom is suspended just in front of the rear tractor wheels, as shown in Fig. 1, the driver can see that all nozzles are operating properly. This allows the tires to come in contact with the herbicides, some of which may be harmful. In this case either the tires should be thoroughly washed or the boom

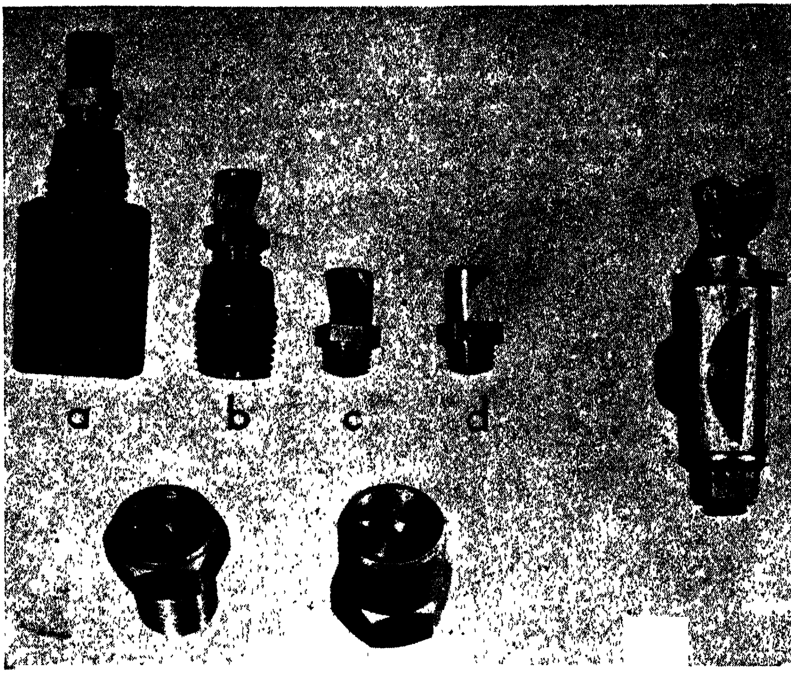

FIG. 2. Some nozzles that deliver a flat fan-spray. Upper row—Skinner greenhouse irrigation nozzles model SS50. (a) fitted with ¼-inch coupling and plug, drilled 5/16-inch diameter and tapped 24 threads per inch. (b) drilled and tapped in ¼-inch plug to fit standard equipment. (c) and (d) SS50 nozzles. This nozzle is also equipped with a strainer and is available as model ST 50. Extreme right—Bordeaux nozzle. Lower row—Monarch nozzles model H-513 (male thread) and model H-512 (female thread).

should be carried behind the tractor. Then a second man would be needed to watch the nozzles.

It has been suggested by most investigators that herbicides be applied with nozzles that produce a sheet-like or fan-shaped spray instead of a conical one because the distribution of the flat-fan spray is more uniform through the swath covered by each nozzle. In our tests the conical spray was about 60 per cent as effective as the flat fan-shaped spray. The Bordeaux nozzle has been used for a good many years to produce a flat-spray but hasn't given as good results with us as have the Monarch flat spray nozzles model H-512 (female thread) and model H-513 (male thread). Monarch nozzles may be obtained that deliver fan sprays with an included angle of from 50 to 100 degrees. These nozzles are available with orifices of various sizes but one with a diameter of .059 inches seems best adapted to this work. This particular nozzle delivers 1.0 gallon per minute with 100 pounds pressure per square inch. A rather heavy jet of liquid is delivered at the edges of the spray fans but otherwise the Monarch nozzles are very satisfactory.

The Skinner greenhouse irrigation nozzle, No. SS–50, may also be used for spraying weeds. This nozzle produces a fan spray with an included angle of 50 degrees. A $^{5}/_{16}$-inch drill, tapped 24 threads per inch, is required as a fitting for this nozzle. The diameter of the orifice is .049 inches and the nozzle delivers .75 gallons per minute at 100 pounds pressure.

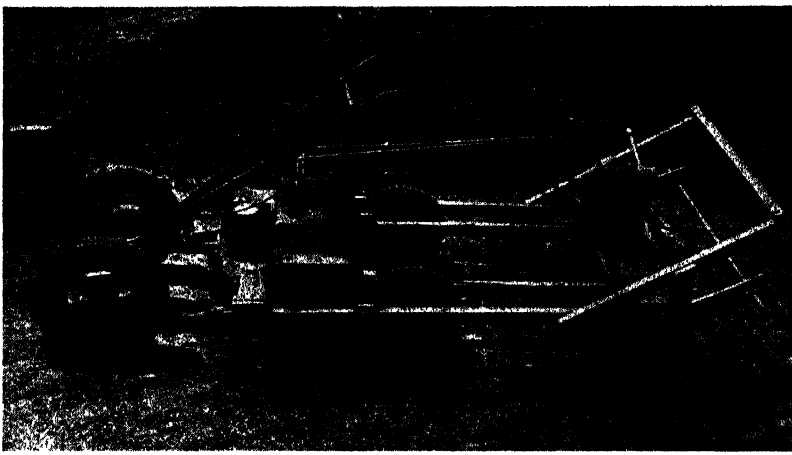

FIG. 3. This home made power rig is designed to spray small acreages. A Planet Jr. tractor, the trailer mounted on two wheelbarrow wheels with a one horse power motor and small pump, develop as much as 100 pounds pressure and spray four rows at once.

FIG. 4. A Field Force sprayer adapted to spraying weeds in fields of carrots and parsnips. The pump is driven by a power take-off from the tractor. Twelve rows are being sprayed here at once; the nozzles are carried at a height so that each spray-fan is covering two rows. This rig will spray two acres an hour.

The Skinner nozzle does not have quite as even a spray across the fan as the Monarch; neither does it have the jets of liquid at the edges of the fan.

Some attention must be given to the factors that determine the speed that the rig must travel in order to apply a given amount of spray per acre. Raynor (10) has given special attention to this problem. This depends on the size of the nozzle orifice, distance between the nozzles, and the pressure at which the spray is applied. Many vegetable growers become confused at first and feel that the number of nozzles on the boom are a factor in determining the speed at which the tractor should operate. Obviously this is not true, because the speed that one nozzle must travel along the row is the same as that at which ten nozzles travel (other things being equal) in order to deliver a given amount of material per unit area. Ten nozzles cover an area with just one-tenth the number of trips across the field but the operating speed of the tractor is the same regardless of the number of nozzles used.

A practical way of calibrating the speed of the rig with the amount of the material applied is to determine the amount of oil used on a small area. For instance, when spraying a 10-foot swath, 2¼ gallons of spray should be used for each 100 feet of row sprayed in order to apply 100 gallons per acre. The speed of the tractor should be adjusted accordingly.

Where the discharge rate of the nozzle is known and the pressure kept constant, the speed at which the tractor should travel can be computed directly.

Example

Problem: Discharge rate of nozzle — 1 gallon per minute.
Distance between nozzles on the boom — 1.5 feet.
Required amount of herbicide per acre — 100 gallons.

Solution:

Reducing an acre to a one-row basis

$$\begin{array}{r} 29{,}040 \text{ feet of row} \\ 1.5 \text{ feet}\overline{)\,43{,}560 \text{ square feet in an acre}} \end{array}$$

1.5 feet divided into 43560 square feet (number of square feet per acre) gives 29,040 feet of row that must be sprayed. This is 5.5 miles of row. One hundred gallons must be applied and the capacity of the nozzle is 1 gallon per minute so that the time required is 100 minutes. In order to travel 5.5 miles in 100 minutes the tractor must move at the rate of 3.3 miles per hour to apply 100 gallons per acre when the rows are 18 inches apart. To apply more spray per acre, drive slower. To apply less spray, drive faster. If the tractor moves at a speed of 4.1 miles per hour, for example, the above equipment will apply about 80 gallons per acre.

If one speed of the tractor is more desirable than another, it is possible to alter the amount of herbicide applied per acre simply by using nozzles with various sized orifices.

Summary

Greater care must be exercised in applying weed sprays than when applying insecticides and fungicides. Almost any type of spray rig may be adapted to the application of selective herbicides, but special nozzles that deliver flat fan-sprays are necessary for best results. Particular attention should be given to the calibration of the tractor speed with the amount of spray delivered per unit of time.

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Comparative Effects of Radiation and Indolebutyric Acid Emulsion on Tomato Fruit Production[1] [2]

By Alice P. Withrow, *Purdue University Agricultural Experiment Station, Lafayette, Ind.*

One of the problems connected with the production of greenhouse tomatoes during the winter is the low percentage of fruit set. This low set is due to faulty pollination caused in turn by the low carbohydrate content of the plant occurring during the cloudy short days of our northern winter (3, 4, 6). It is logical to assume that the carbohydrate content of the plant could be materially increased by the daily use of high irradiances from artificial sources and consequently the fruit set likewise be increased. However, it is not practical to use high irradiances over large tomato plants throughout their flowering period since the cost of power and lamp replacement would be far too great to be commensurate with the additional income. It was thought, nevertheless, that the low carbohydrate condition could be increased, at least initially, by the addition of high irradiances of artificial radiant energy for a few hours each day while the plants were still in the seed flat. The cost of this would be relatively low.

It is generally recognized that growth regulators as indolebutyric acid, B-naphthoxy-acetic acid or 2–4 dichlorophenoxy propionic acid increase fruit set when used on tomato flowers as a substitute for pollination during unfavorable weather conditions (1, 2, 5, 7). Therefore, the present experiment was designed to compare the production of tomato plants given three different treatments: (a) control plants grown by regular greenhouse methods; (b) plants given an initial period of artificial radiation; and (c) plants whose flowers were treated with a growth regulator.

Procedure

Two varieties of tomato, Long Calyx and Michigan State Forcing, were seeded at a spacing of 2 x 2 inches on December 15, 1943, in sterilized flats of soil. One-third of the plants was reserved as controls, one-third was reserved for treatment of the flowers with a growth regulator, and one-third was irradiated. Thirty-two plants of each variety were included for each of the three treatments.

Control Treatment

On January 14, the plants were transplanted to ground beds at 20 x 34 inches spacing, eight plants to a row, four rows per treatment. At the onset of flowering, about February 28, the plants were vibrated daily to aid pollination. They were topped at 8⅓ feet.

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[1]Journal Paper No. 203 of the Purdue University Agricultural Experiment Station.

[2]Acknowledgments: The author expresses her sincere appreciation to Professor E. C. Stair for his cooperation during the course of this experiment, and to Miss Ruth Baldauf for services rendered.

Fruits usually were harvested three times weekly. Data were taken on date of harvest and number and weight of fruit. Harvesting was stopped on July 17.

The temperature of the house was maintained manually at about 75 degrees F during the day and 70 degrees F at night as long as possible. In the late spring and early summer it was not possible to maintain these temperatures. It is realized that the winter temperatures employed were somewhat high for a commercially grown crop.

Radiation Treatment

The irradiation of the plants was begun at the time of the unfolding and greening of the cotyledons. They were irradiated four hours daily from 6:30 p. m. to 10:30 p. m. from a 300-watt internal reflector lamp suspended 24 inches above the tops of the plants. This gave an initial irradiance varying from 750 foot candles at the tops of the seedlings in the center of the flat to 500 foot candles for those at the edges. The plants were kept for 21 days under these conditions and were transplanted to ground beds at the same time as the control plants. Subsequently they received exactly the same treatment as the control plants. The cost per plant of the irradiation treatment averaged about ½ cent.

Growth Regulator Treatment

The plants included here were given the same treatment as the control plants prior to flowering. After flowering, the plants were not shaken to aid pollination, although no precautions were taken to avoid pollination. An indolebutyric acid (I B) emulsion was applied to the fully open individual flowers by means of a nasal atomizer on Monday, Wednesday, Friday and Saturday of each week. The application of the emulsion was continued from the time the first flowers opened on February 28 to June 8.

The indolebutyric acid emulsion was prepared in a Waring blendor according to the method proposed by Withrow, Howlett and Blodgett (8). The formula used was:

0.2 gm γ —(indole–3)–n–butyric acid
1.0 gm polyvinyl alcohol RH–403 (E. I. du Pont de Nemours)
5.0 gms Wax Blend, 65 per cent anhydrous lanolin, 20 per cent carnauba wax, 5 per cent cetyl alcohol
0.2 gm $NaHCO_3$
100.0 mls H_2O

All other treatments were similar to those given the control plants.

Results

The results are given in Table I and in Figs. 1–4. The table shows the average production per cluster for the plants in each of the treatments and the average total production per plant. The graphs show the average cumulative production per plant through the harvest period.

TABLE I—COMPARATIVE EFFECTS OF RADIATION AND INDOLEBUTYRIC ACID EMULSION ON FRUIT PRODUCTION OF GREENHOUSE TOMATOES

Cluster	Long Calyx Variety						Michigan State Forcing Variety					
	Control		Radiation		I B Emulsion		Control		Radiation		I B Emulsion	
	No. Fruit	Wt. Fruit (Gm)	No Fruit	Wt. Fruit (Gm)	No. Fruit	Wt. Fruit (Gm)	No. Fruit	Wt. Fruit (Gm)	No. Fruit	Wt. Fruit (Gm)	No. Fruit	Wt. Fruit (Gm)
1	2.6	267	3.4	358	4.7	440	3.7	327	3.9	387	5.6	574
2	4.1	387	5.2	526	5.5	616	4.5	422	5.7	601	6.4	691
3	4.8	522	5.8	644	5.3	553	4.5	477	5.6	579	5.4	535
4	4.1	507	5.2	585	4.8	552	4.8	501	6.0	614	4.8	473
5	3.0	333	4.4	494	3.7	417	4.5	492	4.5	469	4.9	500
6	4.8	558	4.4	518	4.7	540	3.7	417	4.4	462	4.8	455
7	5.1	590	3.6	398	4.6	503	4.9	574	4.4	481	4.9	497
8	3.5	385	2.6	298	4.0	402	4.2	487	3.6	411	5.1	451
9	1.64	168	2.1	231	2.4	233	3.2	339	2.6	277	3.8	372
10	0.45	43	1.0	108	0.74	81	2.6	269	2.4	239	2.2	186
11	0.22	15	0.1	14	0.2	27	1.5	141	1.1	104	1.1	95
12	0.19	13	0.27	13	0.06	5	1.1	83	0.5	49	0.3	31
Total Average for Long Calyx Cluster 1–5 and Michigan Cluster 1–4												
	18.6	2,016	24.0	2,578	24.0	2,607	17.5	1,727	21.2	2,181	22.2	2,273
Total Average for Long Calyx Cluster 6–12 and Michigan Cluster 5–12												
	15.9	1,772	14.0	1,580	16.7	1,791	25.7	2,802	23.5	2,492	27.1	2,587
Total												
	34.5	3,788	38.0	4,187	40.7	4,369	43.2	4,529	44.7	4,673	49.3	4,860
Total Average Pounds per Plant												
		8.35		9.23		9.63		9.98		10.3		10.7
Average Weight per Fruit (Gms)												
		110		110		107		105		105		99

The radiation treatment caused an increased fruit set on the first five clusters of Long Calyx, but the total production of the clusters beyond the fifth was less than for comparable clusters of the control plants. On Michigan State Forcing, there was increased production on the first four clusters, with a definite drop in production on clusters 7, 8 and 9, and somewhat less production on the last clusters. This indicates that, under the conditions of the experiment, a definite increase in fruit production was brought about on the first clusters by three weeks of irradiation while the plants were in the seed flat. This initial increase was followed by a definite decrease in production in both varieties. The net result was a slight gain in number and weight of fruits picked from the plants given additional radiation. For Long Calyx there was a gain of 10 per cent in number of fruit and 9 per cent in weight; for Michigan State Forcing there was a gain of 3 per cent in number and weight of fruit. The average weight per fruit was about the same as the control fruit average weight.

The I B emulsion caused considerable increase in set on the first two clusters of Long Calyx, with a slight increase on clusters 3, 4 and 5. On the later clusters, the production was about the same as on the control plants, although clusters 7 and 8 produced a little less and clusters 9 and 10 a little more than like clusters of the control plants. In Michigan State Forcing, there was a definitely increased produc-

tion on the first two clusters, with only slightly increased production on the third. The weight production was slightly less on the later clusters of the I B plants as compared to that of the control plants,

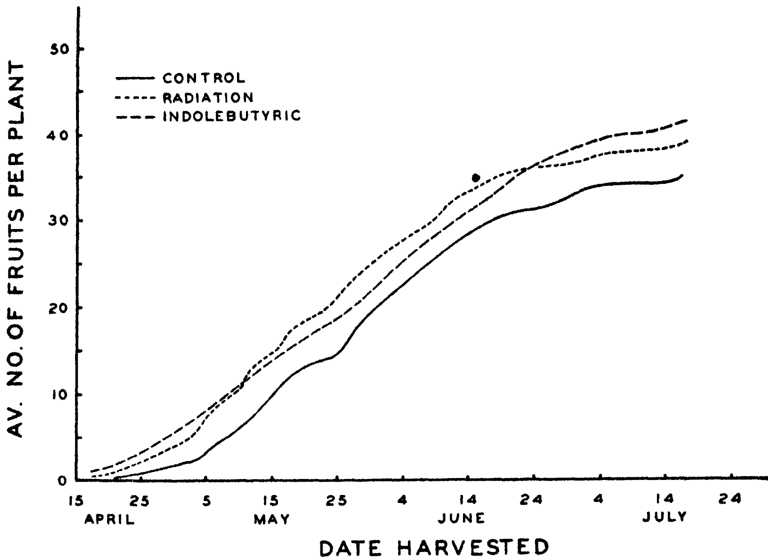

FIG. 1. Cumulative data on number of fruits produced throughout harvest period on Long Calyx tomato.

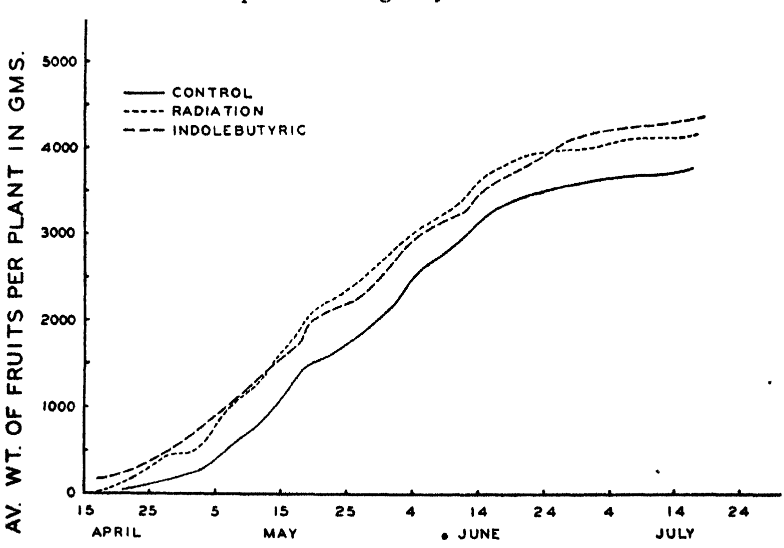

FIG. 2. Cumulative data on weight of fruits produced throughout harvest period on Long Calyx tomato.

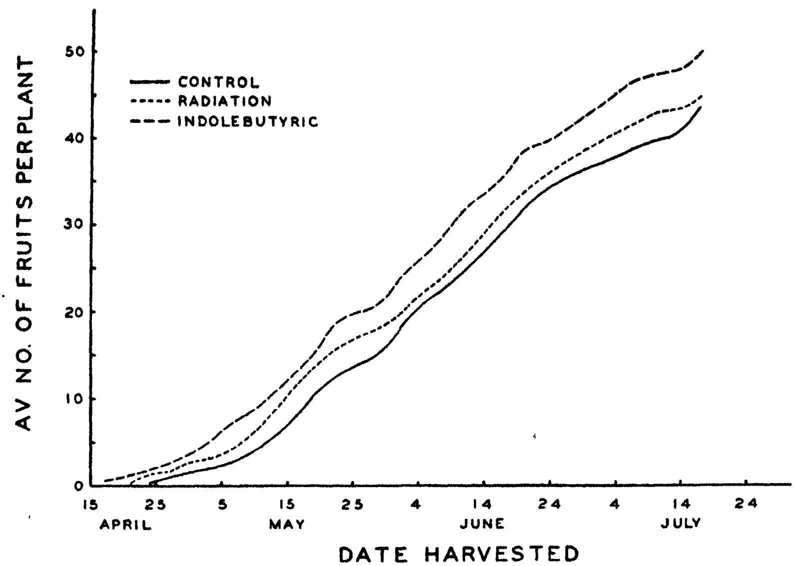

FIG. 3. Cumulative data on number of fruits produced throughout harvest period on Michigan State Forcing tomato.

although there was a slight increase in number of fruit picked. It is interesting to note that the initial increase on the early clusters of Long Calyx was not followed by a decrease, as was the case with the irradiated plants. The total production showed an increase of 18 per cent in number of fruits and 15 per cent in weight of fruit for Long Calyx, and 13 per cent in number and only 7 per cent in weight for Michigan State Forcing. The average weight per fruit was slightly less in the Long Calyx and definitely less in Michigan State Forcing on the I B treated plants as compared to the controls. This decrease in size did not occur on the early clusters, but the fruit on the later clusters were smaller than those on comparable clusters produced by the other treatments, and, therefore, brought down the average for the season.

The curves in Figs. 1–4 again show the early increase in production of the irradiated plants and those treated with the emulsion.

Discussion and Conclusions

The results presented for the radiation phase of the experiment are for one season only, and under more or under less favorable weather conditions similar results might not be obtained. However, it seems worthwhile to present these data since they corroborate earlier results obtained in cooperative experiments with several commercial growers (9).

It appears that a definite increase may be obtained on the first clusters of a late winter or early spring greenhouse tomato crop by giving the plants high irradiances while they are still in the seed flat.

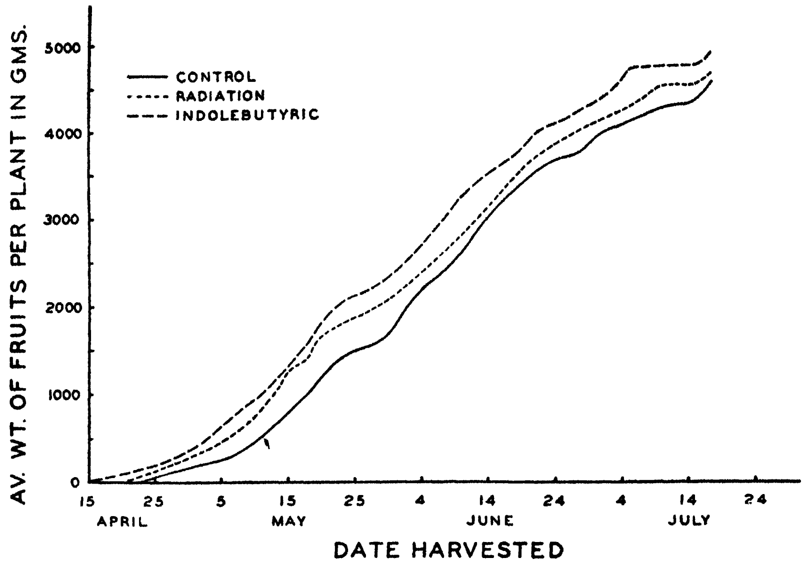

FIG. 4. Cumulative data on weight of fruits produced throughout harvest period on Michigan State Forcing tomato.

However, these initial increases appear to be offset by later decreases, giving only a slight increase in total production over the season. Probably no increase could be expected with additional radiation if the plants were seeded earlier than November 1 or later than March 15.

Harvest was begun seven days earlier on the I B treated plants of Long Calyx than on control plants, and three days earlier on the irradiated Long Calyx plants. With Michigan State Forcing, harvest was begun three days earlier on the I B and irradiated plants than on the controls. The I B plants in both varieties stayed in production as long as the control plants. In Michigan State Forcing, the fruits from the irradiated plants matured slightly faster than did those of the controls, and in Long Calyx some of the irradiated plants were out of production as long as six weeks before final harvest on the control plants. This accounts for the flattening of the production curve of the Long Calyx irradiated plants from June 17 on to the end of harvest. The radiation treatment did not ensure adequate pollination in either variety since many blossoms failed to set fruit.

From these data it appears that the use of growth substances on the flowers of a crop planted at this time may not be worthwhile on the later clusters. Production was not increased by their use when the weather became brighter and the days longer. It is suggested that a combination of irradiation of the plants in the seed flats, together with treatment of the flowers of the first three- to-five clusters with a growth regulating substance, might give better results than either of the treatments used separately.

The incidence of blossom-end rot was low in all cases. There was a slightly increased tendency with the fruits from I B treated flowers, but this was overcome by keeping the soil moisture at adequate levels at all times. There was no tendency toward pointed or misshapen fruit with Long Calyx in any of the treatments. With Michigan State Forcing, the I B treated flowers frequently produced a pointed fruit. The fruit of both varieties often had a green placental pulp in the I B treatment. This appeared occasionally in the control and radiation groups, also. It disappeared almost entirely from all treatments as the season progressed and there was more sunshine and longer days.

While this experiment is in no way conclusive, it does indicate that it may be worthwhile to investigate further the combined effect of early treatment with high irradiances and treatment of the flowers of the early clusters with a growth regulator on late winter or early spring greenhouse tomatoes.

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A Two-Bed Machine for the Band-Placement of Fertilizer and the Seeding of Row Crops on Irrigated Beds[1]

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Under the conditions of Southwestern irrigated agriculture, individual farmers have found it necessary to develop much of their own equipment. Outstanding in locally-developed agricultural machinery is the planting sled for the row-crop or raised-bed method of culture. Some form of the planting sled is standard equipment on every vegetable farm in the Southwest, but at present all units are home-made and vary according to the ideas and needs of the individual.

Griffiths (1) described the construction and operation of a single-bed, wooden sled, which mounted equipment for the band-placement of fertilizer at the time the seed was planted. It planted two rows of seed at any desired width on a standard 40-inch bed. At the same time, a single band of fertilizer was placed at any desired distance from, and depth below, the seed rows.

The original sled was primarily designed for experimental use. Emphasis was placed on the operation of the revolving-cylinder, top-delivery type of fertilizer hopper, which is far more accurate than most gravity feed hoppers, although it is still in the experimental stage.

The new sled discussed in this paper was designed to combine the best principles of home-made sleds in a standardized unit of equipment which could be manufactured economically and rapidly. The result is a sled upon which may be mounted any type of fertilizer and seeder unit.

The following principles are involved in the design of the Southwestern row-crop sled:

1. It should be able to place the fertilizer, shape the bed, level the furrow and plant the seed in a single operation.
2. It should be large enough to be an efficient unit on large truck farms and small enough to be of use to the local market gardener.
3. It should be heavy enough to pack the beds and pulverize clods without bouncing at relatively high rates of speed; and it should be light enough to be drawn easily by medium weight, wheeled tractors.

[1]Appreciation is extended to Mr. Carl Spain, Tempe, Arizona, for the actual manufacture of the machine, and for original ideas which greatly improve its efficiency.

Appreciation is also extended to members of the Bureau of Plant Industry, Soils and Agricultural Engineering of the United States Department of Agriculture, for their aid in calibrating the fertilizer hoppers used in this work.

4. It should be of all-steel construction to resist wear and weather, and should be so designed that the planters, fertilizer units, and other tools may be rapidly dismounted.

As pointed out by Griffiths (1), there are two general methods of pre-planting fertilizer applications on row crops in the Southwest. The first is the broadcast method, in which the chemicals are applied to the land before furrowing. Relatively low application rates of fertilizer are the rule in the Southwest. This practice, combined with the high rate of fixation or leaching on alkaline soils under irrigation, results in a minimum amount of the actual nutrients arriving at the root zone of the row-crop.

In the second method, called band-placement, the fertilizer may be applied in two bands, one on either side of the ridge at the time the land is ridged or furrowed. This latter method is preferable to broadcasting, but is highly inaccurate because the band is broken and partially mixed with the soil when the sled is drawn over the ridge during the planting operation. Reduction in stand from fertilizer burning is often observed when this method of fertilizer application is used.

The disadvantages of both of the above methods of fertilization are overcome when the fertilizer is band-placed at the same time that the seed is planted. The increased accuracy of placement by this method makes a maximum amount of nutrients available to the plant; thus, lower applications of fertilizer per acre are needed.

Description of the Steel Two-Bed Planting and Fertilizing Sled

Fig. 1 shows the complete two-bed, all-steel sled unit, mounting two Cole revolving-cylinder, top-delivery fertilizer hoppers. The sled is designed to fit two 40-inch beds, and to place four 1½ inch bands of fertilizer on the furrow side of each of the four seed rows. The fertilizer shoes are rapidly adjustable for depth or hortizontal distance from the seed row. The central runner is shortened to allow room for the ground wheel to follow in the middle furrow. It is necessary for the ground wheel to ride in the furrow rather than on top of the bed in order to avoid excessive slippage due to loose soil.

The seed hoppers, which are of standard make, are pulled behind the fertilizer units and may be adjusted for width between rows by shifting them horizontally.

The ridges thrown up by the lister shovels during ground preparation are compressed and shaped into flat-topped beds, 6 to 10 inches high, by the shaper plates. The shaper plate is of a funnel type and compresses and breaks up all clods. The fertilizer shoes tend to tear up the sides of the beds, but a light funnel-type shaper plate behind the fertilizer shoes leaves the bed in ideal condition for planting.

The seed planters are controlled by levers operated by the man riding the sled. Any desired depth of covering is obtained by increasing or lessening the tension of the springs against the seed hoppers. Fig. 2 illustrates the position of the planter units and the ground

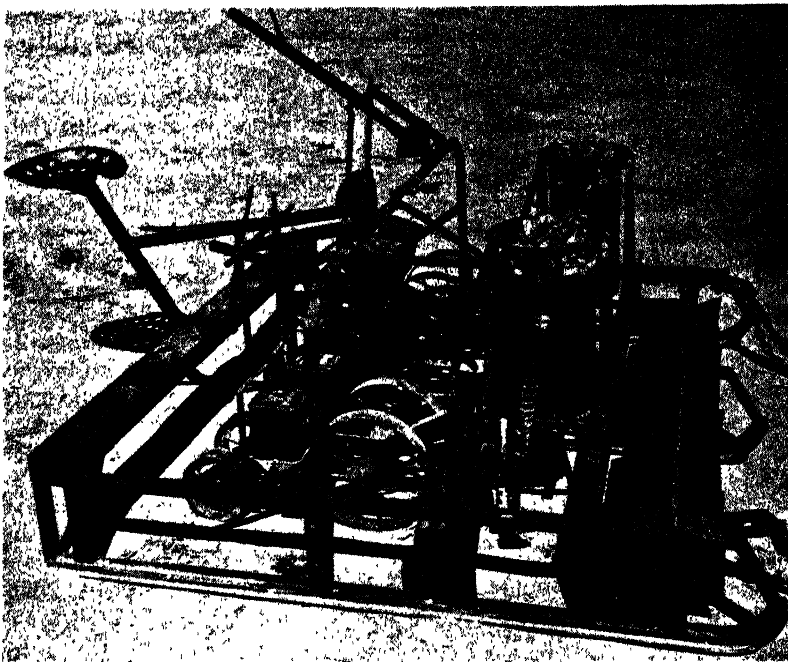

FIG. 1. Two-bed fertilizer and planter sled. Top-delivery fertilizer hoppers and funnel-type shaper plates.

wheel. A chain drive transmits power from the ground wheel to the counter shaft which operates both fertilizer hoppers. The counter shaft should be mounted in friction lock bearings so that it can be easily removed in order to change Sprocket B (See Fig. 3).

Fig. 2 also illustrates the method of power transmission from the counter shaft to the hopper. The same method may be used for gravity feed hoppers. Note the mounted bearing of the ground wheel just below Sprocket B. The ground wheel must move freely in a vertical direction; therefore its bearing must have full play.

Specifications and a list of parts for the two-bed sled may be obtained from the Department of Horticulture, University of Arizona, Tucson, Arizona.

Operation of the Top-Delivery Fertilizer Hopper

The revolving-cylinder, top-delivery fertilizer hopper is in an experimental stage. It is highly accurate and particularly adapted to the band-placement of relatively small quantities of most commercial fertilizers. With some refinements it may become commercially available in the near future.

Gravity feed hoppers are adjusted for rate of application by the use of plates in the bottom of the hopper. Top-delivery hoppers are adjusted for rate of application by changing the sprocket ratios in the

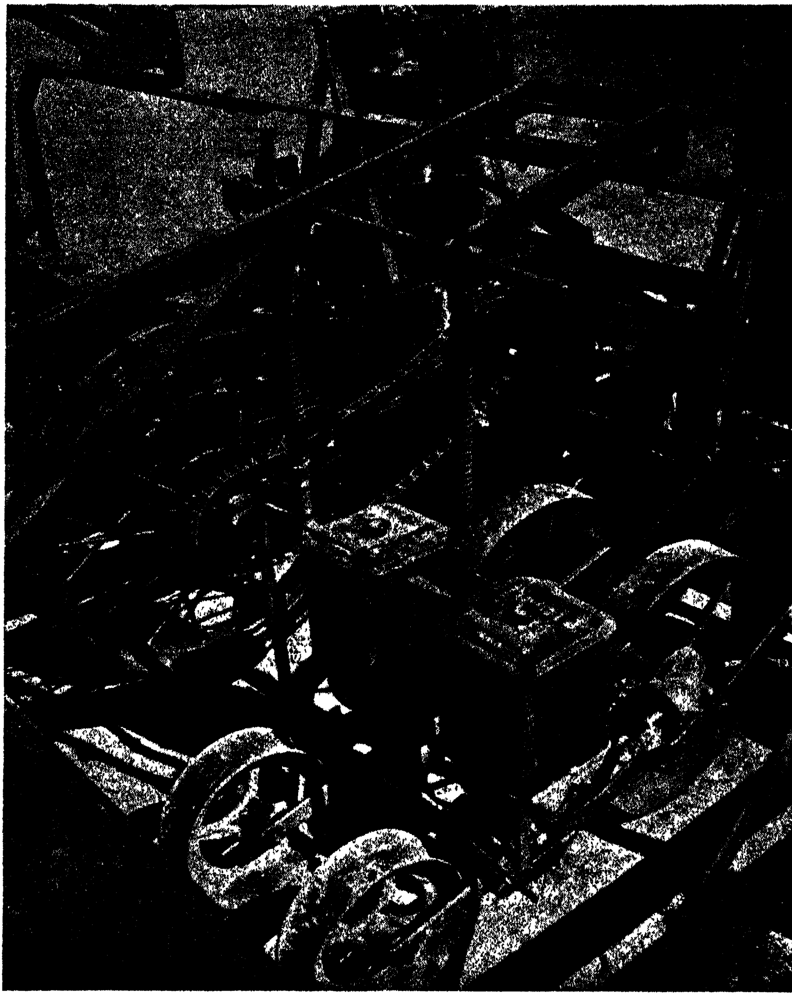

FIG. 2. The ground wheel and position of planter units on the two-bed sled.

power transmission system. At present no simple method of calculating the necessary gear ratios for changes in rate of fertilizer application has been developed for commercial use.

This paper presents a method by which the hoppers may be adjusted for commercial use with a minimum of mathematical calculation. Table I is not complete in that it does not take into consideration variable bed widths, but is based on a standard 40-inch bed and a 24-inch ground wheel. The figures under the letters B, C, and D in Table I represent the number of teeth per sprocket necessary for the predetermined amounts of fertilizer delivery. The position of sprockets B, — C — D may be determined from Fig. 3.

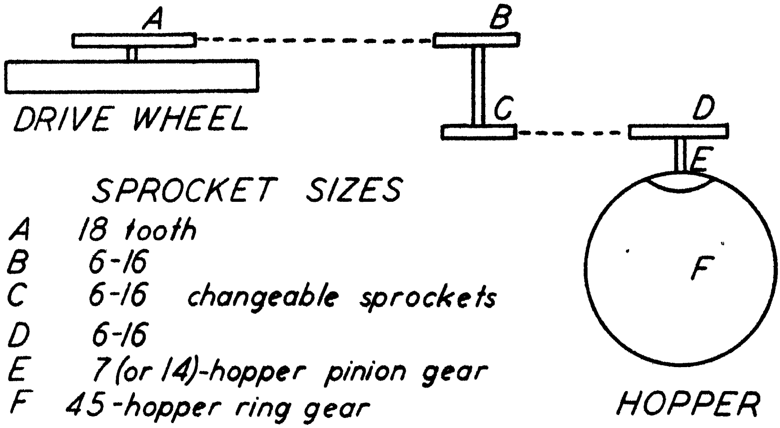

FIG. 3. The location of the gears necessary to determine the rates of fertilizer application with the revolving-cylinder, top-delivery type of fertilizer hopper.

TABLE I—SPROCKET RATIOS FOR THE TOP-DELIVERY HOPPER FOR APPLICATION OF VARIOUS QUANTITIES OF FERTILIZERS OF KNOWN WEIGHT PER HOPPER*

Weight of Fertilizer in 10-inch Hopper When Full (Pounds)	Pounds per Acre								
	100	150	200	250	300	350	400	450	500
	Positions of Sprockets in Diagram 1								
	B C D	B C D	B C D	B C D	B C D	B C D	B C D	B C D	B C D
35	16– 7–11	9– 7–13	8– 7–11	6– 6–10	9–14–13	6–10–12	8–14–11	6–14–13	6–12–10
40	16– 9–16	12 10–16	9–10–16	9–11–14	6–10–16	6– 8–11	6–10–12	6–15–16	7–11– 9
45	13– 6–15	10 6–13	14–13–15	12–13–14	9–10–12	8–13–15	7–13–15	6–10–12	6–13–14
50	16– 7–16	9– 6–16	9– 6–12	9–10–16	6– 6–12	6– 7–12	11–16–13	6– 6– 8	6–10–12
55	15– 6–16	14– 8–15	14–10–14	9– 8–14	11–10–12	13–15–13	7–10–14	7– 8–10	7– 8– 9
60	16– 6–16	16– 9 16	10– 6–13	8– 7–15	9–10–16	9–11–15	9–10–12	6–10–16	7–13–16

*The sprocket ratios are determined for a ground wheel 24 inches in diameter. A wheel of this diameter makes 2,050 revolutions per acre where 40-inch beds are used. If larger or smaller spacings are used, additional charts must be consulted. These may be obtained from the Bureau of Agricultural Chemistry and Engineering, U.S.D.A., Washington, D. C.

The figures, 35 to 60 pounds, which indicate the weight of the fertilizer in a standard 10-inch Cole hopper, include the volume weights of nearly all commercial fertilizers. Thus the sprocket ratios given in Table I are applicable to most commercial fertilizers if the hopper is driven by a 24 inch ground wheel and if the spacing between beds is 40 inches. For other spacings, reference must be made to charts obtainable from the Bureau of Plant Industry, Soils and Agricultural Engineering, U. S. D. A., Washington, D. C.

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Propagating Cabbage by Root Cuttings

By C. L. Isbell, *Alabama Agricultural Experiment Station, Auburn, Ala.*

Workers concerned with cabbage breeding problems often experience difficulty in increasing and carrying stock from season to season to provide material for producing seed later. This is especially true with types or strains that possess undetermined genetic qualities with respect to seeding tendencies.

It is generally accepted that fall-grown cabbage in the South seed the following spring, provided they head in the fall and are exposed to low temperatures during the winter. However, this does not always occur. For example, fall-headed plants of several interesting types or varieties were produced from home-grown seed and carried over the winter of 1944–45 in an unheated greenhouse at Auburn where the temperature went low enough a few times to cause ice to form on the heads. Some of these produced flowers and seed in the spring of 1945. Others produced flowers but no seed, while still others failed to produce even flower stalks. This would indicate that different amounts of chilling are required to encourage seeding in various kinds. When working with such non-uniform stocks, it is necessary to propagate by vegetative methods until enough is known about their possible seed-production habits to assure maintenance of the stock by means of seed.

In studying characteristics of new strains to determine their possible value for breeding purposes, it is desirable to examine the various parts of the plant rather thoroughly. This may use or destroy parts of the plant that function in the production of seed. It is important, therefore, to breeders to be able to propagate or establish new plants by vegetative means.

In a previous paper (1) citation was made to a rather old method of vegetative propagation of the cabbage by means of lateral slips from stem buds, which was practiced by Lindly (1831) and Kendall (1883). In the same paper a method of propagating cabbage by means of leaf cuttings was described. Later, Detjen (2) explained a vegetative method he used to propagate the cabbage "by means of offset-like growth produced on seed branches."

Apparently all of the vegetative methods of propagating the cabbage previously reported, except the leaf method (1), depend for success on the use of plant parts that developed only at certain seasons. In the South where both a spring and fall crop of cabbage may be grown, vegetative methods of propagation that permit the use of material selected at any season appear to offer considerable opportunity for speeding up cabbage-breeding programs. It was thought that roots might offer a means of propagation.

Preliminary observations of the root method of propagating were made on 18 root cuttings taken on January 11, 1945, from a large Savoy-type plant that was growing in the open from an August 1 transplanting. The cuttings consisted of roots removed from the base or crown of the plant. They ranged from about 4 to 6 inches long, and

the largest ones were approximately the size of an ordinary lead pencil at their greatest diameter. These were placed in sand in a bed in the greenhouse so that about one-fourth inch of the root extended above the sand. The cuttings were provided with a glass cover and partial shade. Some shoots were visible by January 14, or within 3 days from the time the cuttings were placed in the bed. Within 16 days all of the cuttings had developed one or more shoots. The cuttings were transplanted to pots February 8 and observed until the latter part of March, by which time each had developed five or more shoots. Later the plants from nine of the pots were transplanted to the open and nine were allowed to remain in the greenhouse for further observations. They grew well in each location. Those in the open as they appeared April 11, or 90 days after the cuttings were taken, are shown in Fig. 1. These, as well as those remaining in pots in the greenhouse, were continuing normal development on May 28.

As soon as it was learned that roots could be used for propagation, the method was employed for saving and increasing selected stock in the Station's breeding program. The procedures used and the results reported are for 1945.

FIG. 1. Cabbage of a large, late Savoy strain produced from root cuttings as they appeared in the garden April 11 or 90 days after the cuttings were taken.

FIG. 2. Plants of a small Savoy strain as they appeared when removed from the bed 41 days after cuttings were taken.

FIG. 3. Plants of a round Charleston Wakefield type as they appeared 22 days after cuttings were taken.

Ten root cuttings were taken March 1 from a headed plant of late small-heading, Savoy type, and were handled the same as those in the preliminary test. In 18 days from the time cuttings were made, buds were showing on three of the cuttings and within 41 days all cuttings had produced shoots with an average of three shoots per cutting (Fig. 2). All of these were successfully transplanted first to pots and most of them later to the open where they were growing well May 28. Root cuttings from similar plants were taken May 5 and May 17, respectively. Shoots were beginning to show on these May 24 and May 28, respectively.

Twelve root cuttings were taken March 1 from a round Charleston Wakefield type that was early and of high quality. By March 23, or within 22 days, all of these cuttings had produced shoots (Fig. 3).

An all-green head type had been transplanted to a tub in the greenhouse for seeding purposes prior to March 19. There was doubt as to whether this plant would seed, and root cuttings were made. Some

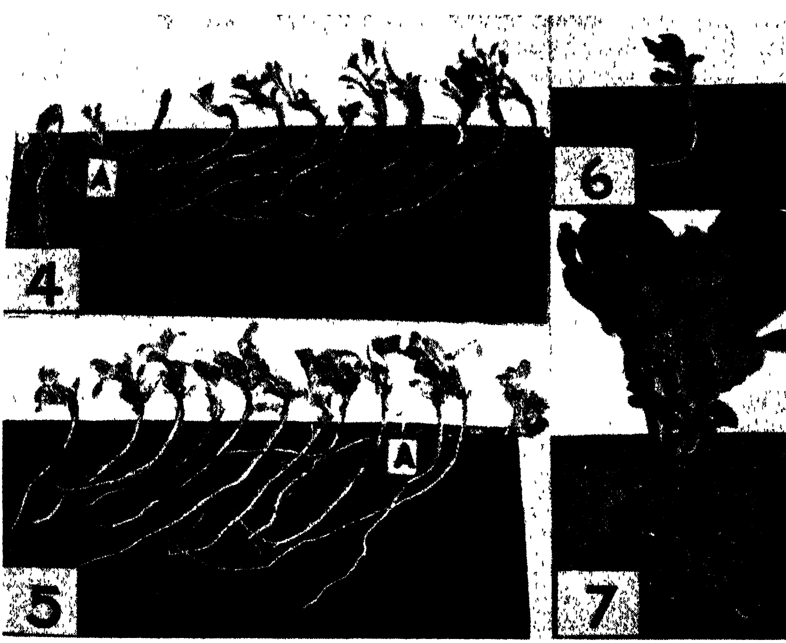

Fig. 4. Plants of an all-green head type as they appeared 22 days after the cuttings were taken. (A)—A plant that appeared 4 to 6 inches below the surface of the soil on a root before the cuttings were taken.

Fig. 5. Plants of a large attractive blue-green type as they appeared 22 days after the cuttings were taken. (A)—A plant that appeared below the terminal on a root that was placed in the bed horizontally.

Fig. 6. A plant from a selection made in South Alabama as it appeared 25 days after the cutting was placed in the propagating bed.

Fig. 7. A plant from a root cutting as it appeared unpruned some time after it had been transplanted to a garden.

of the cuttings produced shoots in 7 days and all within 12 days. It was found that one small root located about 6 inches below the surface of the soil had differentiated a shoot, as shown at A in Fig. 4, before the parent plant was taken up the second time. This possibly resulted from an injury caused at the time of first transplanting.

On March 19, 12 root cuttings were taken from a headed plant of a large, attractive blue-green type. These cuttings were kept in the bed for 22 days. These are shown in Fig. 5. It is noted that shoots may appear from points other than the terminal part of the cuttings if the cutting is placed horizontally in the sand, as shown at A in Fig. 5.

On the morning of April 13, root cuttings were taken from 13 plants selected from a field of cabbage at Atmore, Alabama. These were brought to Auburn and placed in sand the next morning. The cuttings from one plant were very small. These and some of the cuttings from other plants were lost in the bed due to over watering and possibly from getting too hot, but most of the cuttings developed shoots within less than a month's time. One of the cuttings brought from Atmore is shown in Fig. 6 as it appeared 25 days after it was placed in the propagating bed.

Although some types or strains of cabbage appeared to regenerate tops quicker than other, all types produced shoots in a relatively short time and in general the several types propagated by root cuttings when transplanted to the garden grew well. One such plant (unpruned) is shown in Fig. 7 as it appeared on May 9 after it had grown in the garden for some time. A few of the plants of the different types were pruned to single stems after they were transplanted to the open. These were growing well on May 28 and appeared to be normal plants.

These studies show that root cuttings offer an easily performed, dependable, and rapid method of propagating a given strain of cabbage.

The method provides a valuable means of increasing selected plants in breeding programs that apparently may be used during any season of the year.

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Propagation and Culture of Garden Sage in Tennessee

By J. P. OVERCASH, *West Tennessee Agricultural Experiment Station, Jackson, Tenn.*

INTEREST in domestic production of garden sage *(Salvia officinalis)* increased rapidly when the foreign supply was cut off by the war in Europe. The sage consumed in the United States at that time was imported largely from the Mediterranean region of Europe (1, 2). Production of garden sage in this country needed to be increased. The high price of sage, due to the domestic shortage, constituted a considerable inducement to farmers to grow this crop. Lack of seeds and plants, however, retarded the expansion of acreage.

PROPAGATION

At the time the shortage of sage developed, the supply of sage seed also was extremely low. Garden sage plants produced from seed vary a good deal in width of leaves and general vigor (1). A uniform lot of plants can be obtained from cuttings made from desirable plants. The percentage of cuttings that form roots under ordinary propagation methods is low. In an attempt to obtain a means of increasing the number of cuttings that form roots, an experiment was conducted in which four commercial plant hormone powders were used to stimulate root formation.

Cuttings were made from old plants with desirable leaf characteristics. The cuttings were made from the last 3 or 4 inches of the stems, and all but two or four of the terminal leaves were removed. The check, or untreated, cuttings were placed in the sand propagation bed in the greenhouse without treatment. The basal ends of the cuttings which were to be treated with plant hormone powders were dipped in the dry powder; the excess powder was shaken off, and the cuttings were placed in the sand propagation bed in the greenhouse. Thirty cuttings were used in each treatment of each replication. After 5 weeks in the bed the cuttings were removed and the number with roots was recorded for each treatment. Rootone was obtained from Merck and Company, Rahway, New Jersey. The hormodin powders were obtained from the American Chemical Paint Company, Ambler, Pennsylvania.

The results of these trials may be seen in Fig. 1. These results are the totals for 22 replications and represent 3,300 cuttings. The trials were carried out from September, 1942, to October, 1943, in the greenhouse at the West Tennessee Experiment Station. All of the plant hormone powders caused an increase in the number of cuttings with roots. The results in per cent of cuttings with roots were as follows: Check, 58 per cent; Rootone, 74 per cent; Hormodin No. 1, 75 per cent; Hormodin No. 2, 79 per cent; Hormodin No. 3, 84 per cent. Not only were the numbers of cuttings with roots increased by these treatments, but the amount of roots per cutting and the general vigor also were increased. The fewest roots were formed

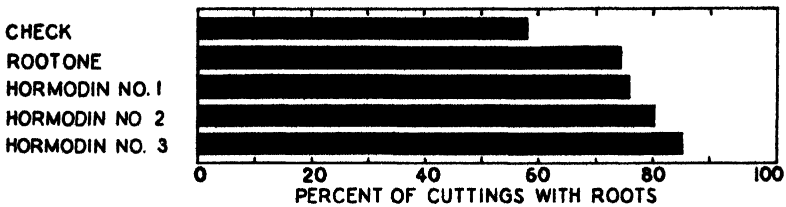

FIG. 1. Effects of four commercial plant hormone powders on formation of roots by cuttings of garden sage *(Salvia officinalis).*

by the untreated cuttings (Fig. 2), and the most by the cuttings treated with Hormodin No. 3. Other treatments were intermediate.

SEED PRODUCTION IN TENNESSEE

Garden sage plants blossom and produce seed in early spring in Tennessee. We have not observed any blossoming in the field except in early spring.

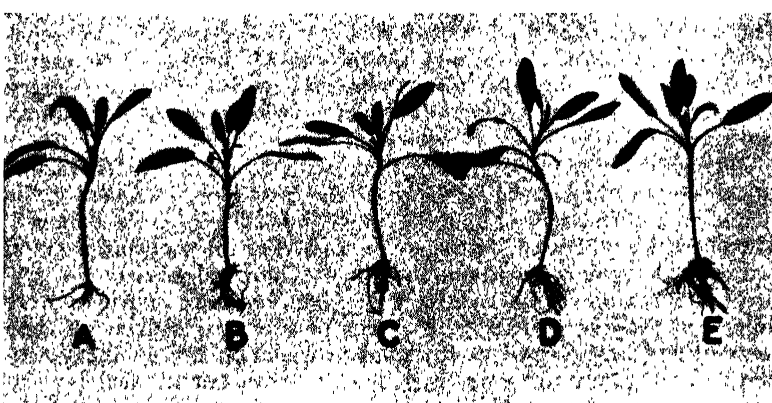

FIG. 2. Root formation as affected by four commercial plant hormone powders. A, Check; B, Rootone; C, Hormodin No. 1; D, Hormodin No. 2; E, Hormodin No. 3.

In order to determine the effect of photoperiod on blossoming of *Salvia officinalis,* an experiment was conducted in the greenhouse from January to March of 1943 and repeated in 1944. Nine plants were given natural day-length, nine were given short days (9 hours by means of cages that could be darkened), and nine were given long days (18 hours of daylight supplemented with Mazda lamps). The results indicate that long days are favorable for flowering in *S. officinalis* (Fig. 3). When cuttings were potted and used in the trials, no blossoms were produced in the shortday treatment. Blossoms were produced in the natural length of day but were not as numerous or as large as those produced in long days. Plants that were larger, and

FIG. 3. Garden sage plants subjected to long and short days. A, 40 short days (9 hours); B, 40 long days (18 hours).

had been grown for several months in the greenhouse and coldframe before the trials began, exhibited a response directly proportional to the length of day. Very few blossoms were produced and many blossom buds were aborted in the short day. In the long day the plants bloomed profusely, and in natural length of day the amount of blossoms produced was intermediate.

HARVESTING SAGE AND YIELDS

The sage leaves and tender stems were harvested with pruning shears when the stems were 3 to 5 inches long. The sage then was air-cured in the shade, on screen drying racks, without supplementary heat. The first year, only two or three harvests were made, but afterward there were usually four harvests each year. One plot of 1/75 acre yielded at the rate of 1360 pounds per acre of air-cured sage the first year; 3900 pounds the second year; and 2066 pounds the third year. We conclude that satisfactory yields of high-quality garden sage can be grown in Tennessee.

MULCHING

In Tennessee there are often periods of dry weather during the summer. An experiment was conducted in 1943 and 1944 to determine the effect of an oat-straw mulch on the production of leaves

and tender stems by garden sage plants. Nitrate of soda was applied to both the mulched and non-mulched plots at the rate of 120 pounds per acre to counteract the denitrification under the straw mulch. Size of plant and general vigor was increased by the straw mulch. Two plots of $1/75$ acre each, set in March, 1944, and mulched, gave a yield at the rate of 2015 pounds of air-cured sage per acre. The two unmulched plots produced at the rate of 1475 pounds per acre. Mulching resulted in an increased yield of garden sage in the summers of 1943 and 1944.

Plant-spacing Trial

There has been considerable variation in the recommendations for spacing plants in the field (1, 2). In order to determine the desirable distance to space plants in Tennessee an experiment was conducted in 1943 and 1944 with plants spaced 18, 24, and 36 inches apart in rows 3 feet apart and 28 feet long. One-row plots were used with six replications. The 18-inch spacing gave better yields than the wider spacings (Table I).

TABLE I—Yield in Pounds per Acre of Air-Dry Garden Sage Leaves and Stems from a Plant-Spacing Trial in 1943 and 1944, at West Tennessee Experiment Station, Jackson

Year	Spacing in Row		
	18 Inches (Pounds)	24 Inches (Pounds)	36 Inches (Pounds)
1943	1,208	941	667
1944	3,868	3,011	2,295
Av	2,538	1,976	1,481

Fig. 4. Three-year-old garden sage mother plant of Tennessee clon No. 15.

Clons of Garden Sage

Many variations in width of leaves and general vigor occur in a seedling population. A clon can be established by asexual propagation from a single seedling plant. We have established several clons of sage in Tennessee, and Fig. 4 shows the mother plant of Tennessee No. 15, which is unusually vigorous and has broad leaves. These clons are being tested for yield and adaptation to Tennessee growing conditions.

Summary

1. Cuttings of garden sage *(Salvia officinalis)* formed more roots when they were treated with certain plant hormone powders before they were placed in the propagation bed.
2. Garden sage plants blossomed and produced seed in early spring in Tennessee.
3. Flowering in *S. officinalis* was inhibited or retarded by short days (9 hours) and was promoted or accelerated by long days (18 hours).
4. The yield of air-cured sage varied from 667 to 3900 pounds per acre per year, depending on treatment and age of plants.
5. Garden sage plants mulched with oat straw grew larger than plants kept cultivated.
6. Plants spaced 18 inches apart in rows 3 feet apart, gave better yields than those spaced either 24 or 36 inches.
7. Desirable clons of garden sage can be established by cuttings from broad-leaved, vigorous plants, which may be selected from a seedling population.

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Effect of Maturity on the Vitamin Content of Green Snap Beans[1]

By Aubrey D. Hibbard and Laura M. Flynn, *University of Missouri, Columbia, Mo.*

Edible quality in green beans is commonly associated with size of the pods. This vegetable, however, is utilized for food at all stages of maturity. Even after the pods become too fibrous to be palatable, the seeds are used as fresh shelled beans. For commercial purposes only the immature pods are desired, and a premium is paid for the smaller sizes.

Studies by other investigators indicate that the smallest pods may not be the most nutritious when the vitamin content is considered. Both Mack and associates (1) and Caldwell and associates (2) have shown that the vitamin C content of green beans increases with maturity of the pods. The concentration in the pods decreases slightly while there is a rapid increase in the seeds. Other workers (3, 4) report either no change with maturity or a slight decrease. The younger shorter beans have been found (5) to be higher in provitamin A or carotene than those longer and more mature.

The purpose of this study was to secure a complete picture of the changes in vitamin content of green beans through progressive stages of maturity for both the fall and summer crops.

Experimental Procedure

The variety Tendergreen was used throughout this study since it is most widely planted for canning and market in this State. Crops were grown under the conditions prevailing at Columbia, Missouri, in the fall of 1943 and summer of 1944. The fall crop was planted at weekly intervals from July 21 to August 15, and the entire crop harvested October 3. The summer crop was planted on May 20. This planting was divided into triplicate plots which were harvested during the month of July as the beans reached the desired stages of maturity. This was done to secure information on the practicability of attempting to harvest this crop at predetermined stages of development.

The beans were harvested in the afternoon and held in a refrigerator at 34 degrees overnight. The following morning they were graded and prepared for analysis. Grading into the several maturity stages was done according to the length of the developing seed. This was found to be more reliable than grades based on external appearances or pod measurements. The maturity grades are described as follows:

Maturity Stage I:—Seed less than 7mm in length. The pods were immature for the variety, about 3½ inches long, dark green in color and somewhat flattened.

Maturity Stage II:—Seed from 7 to 10mm in length. These pods had almost reached their full growth in length, were lighter green in

[1]Contribution from the Department of Horticulture, Missouri Agricultural Experiment Station, Journal Series No. 972.

color and almost round with the transverse and suture diameters approximately equal. This is the stage at which this variety reaches peak market quality.

Maturity Stage III:—Seed from 10 to 14 mm in length. At this stage the pods were showing well defined indentation between the seeds. The endocarp was beginning to collapse in the largest beans but the pods were still edible.

Maturity Stage IV:—Seed from 14 to 18mm in length. The pods had reached their maximum development but were still green. The endocarp had become completely compressed but the seed were still growing. The pods at this stage are seldom used for food.

Maturity Stage V:—Seed over 18mm in length. The pods were turning yellow and decreasing in size. The seed had reached its full development; showed definite color markings but was still succulent.

Samples for ascorbic acid determinations were shelled directly into metaphosphoric acid. The material for all other vitamin tests was given a sharp freeze immediately after separating the seeds from the pods and held at — 40 degrees F until analyzed.

The following analytical methods were used:

Carotene:—Moore and Ely (6). The beans were blanched and extracted with 85 per cent methyl alcohol before chromatographic absorption.

Ascorbic Acid:—Titration. Method of Bessey (7).

Thiamine:—Thiochrome method of Conner and Straub (8).

Riboflavin:—Microbiological method of Snell and Strong (9).

Niacin:—Microbiological method of Snell and Wright (10).

Results

Table I gives a description of the beans at the stages of maturity studied, together with yield records for the summer crop for 1944. Yields for the plots gathered at the first two stages were practically the same. The inhibitory effect of maturing seed is extremely pronounced but may have been exaggerated by the unfavorable weather

TABLE I—Characteristics and Yields of Green Beans, Summer Crop

External Appearance Used in Harvesting	Median Diameter (Inches)	Pod Length (Inches)	Pod Weight (Gms)	No. of Pickings	Yield Ave. 50-ft. Row (Pounds)
	Stage I, Seed <7mm				
Pods less than 4 inches long. . .	21/64	3.7	4.9	6	23.9
	Stage II, Seed 7–10 mm				
Full length and round.	25/64	4.8	5.9	6	24.0
	Stage III, Seed 10–14 mm				
Indented between seeds.	28/64	4.9	6.8	5	14.4
	Stage IV, Seed 14–18 mm				
Green but soft	30/64	5.0	10.0	3	10.5
	Stage V, Seed >18 mm				
Turning yellow.	31/64	5.1	10.1	2	6.5

for pollination and setting that prevailed during this season. Such conditions are, however, not unusual for the summer crop in Missouri. The total production of vitamins on an acre basis was highest when the beans were picked at the second stage of maturity.

Data from the vitamin determinations are presented in Tables II and III. As the seed mature, the dry matter increases from 10 to 30.0 per cent. In this study the least mature seed contributed only 2 per cent of the total dry matter, while the most mature seed contributed 57 per cent.

TABLE II—VITAMIN CONTENT OF GREEN BEANS AT PROGRESSIVE STAGES OF MATURITY, ASGROW TENDERGREEN, FALL CROP

Stage of Maturity	Relative Weight		Dry Matter (Per Cent)	Vitamins Per 100 Gms Fresh Beans: Carotene (Mcg)	Ascorbic Acid (Mg)	Thiamine (Mcg)	Riboflavin (Mcg)	Niacin (Mg)
				Stage I				
Seed <7mm. . .	Pods	97 6	9.5	368.5	19.7	64.5	66.4	0.43
	Seed	2.4	14.5	6.0	1.0	18.1	48.6	0.04
	Whole	100.0	9.6	374.5	20.7	82.6	115.0	0.47
				Stage II				
Seed 7–10 mm	Pods	95.2	10.0	292.2	19.2	57.0	57.1	0.27
	Seed	4.8	11.2	10.1	1.9	18.4	62 9	0.07
	Whole	100.0	10.0	302.3	21.1	75.4	120.0	0.34
				Stage III				
Seed 10–14 mm.	Pods	89.6	10.2	156 0	17.5	47.7	54.2	0.37
	Seed	10.4	18.4	17.4	4.7	59.5	47.6	0.18
	Whole	100.0	11.0	173.4	22.2	107.2	101.8	0.55
				Stage IV				
Seed 14–18 mm.	Pods	74.2	11.6	148.2	19.9	25.3	63.8	0.65
	Seed	25.8	29.0	26.7	12.4	102.2	35.4	0.61
	Whole	100.0	16.1	174.9	32.3	127.5	99.2	1.26
				Stage V				
Seed >18 mm. . .	Pods	61.1	13.9	120.4	14.7	21.4	49.5	0.46
	Seed	38.9	34.2	27.7	16.3	103.1	46.3	0.92
	Whole	100.0	21.8	148 1	31.0	124.5	95.8	1.38

The concentration of all vitamins, with the exception of carotene, was higher in the seed than in the pods.

The pods contribute most of the carotene. The content of this vitamin in the whole beans decreases with increasing maturity. The fall crop was much richer in this vitamin, especially during the early stages.

The ascorbic acid content gradually increased with maturity. In all except the most mature beans the ascorbic concentration was higher in the seeds than in the pods, but the large proportion of pods to seed decreases the comparative contribution of this vitamin by the seed. The crop maturing in summer contained approximately 25 per cent more than the fall crop.

The thiamine concentration of both pods and seed decreased with maturity. The concentration of the vitamin in the seeds was approximately ten times that in the pods so that as the beans mature the total

TABLE III—VITAMIN CONTENT OF GREEN BEANS AT PROGRESSIVE STAGES OF MATURITY, ASGROW TENDERGREEN, SUMMER CROP

Stage of Maturity	Relative Weight		Dry Matter (Per Cent)	Vitamins Per 100 Gms Fresh Beans				
				Carotene (Mcg)	Ascorbic Acid (Mg)	Thiamine (Mcg)	Riboflavin (Mcg)	Niacin (Mg)
				Stage I				
Seed 7 mm	Pods	97.7	10.11	127.4	20.3	56.7	68.9	0.527
	Seed	2.3	8.52	10.1	1.7	7.5	27.4	0.036
	Whole	100.0	10.08	137.5	22.0	64.2	96.3	0.563
				Stage II				
Seed 7-10 mm..	Pods	94.0	11.37	136.4	29.2	56.5	66.3	0.547
	Seed	6.0	17.52	24.7	3.1	22.0	42.6	0.108
	Whole	100.0	11.74	161.1	32.3	78.5	108.9	0.655
				Stage III				
Seed 10-14 mm.	Pods	89.2	11.76	140.2	21.9	56 1	58.9	0.675
	Seed	10.8	22.18	25.4	5 6	33 3	33.9	0.222
	Whole	100.0	12.88	165.6	27.5	89.4	92.8	0.897
				Stage IV				
Seed 14 18 mm.	Pods	77 5	13.19	129.8	25.0	35.8	43.2	0.581
	Seed	22.5	33.63	26.0	10.7	69.4	28.9	0.557
	Whole	100.0	17.79	155.8	35.7	105.2	72.1	1.138
				Stage V				
Seed 18 mm .	Pods	51.6	15.37	38.8	12 9	23.0	27.7	0.308
	Seed	48.4	47.25	15.5	8.2	180.6	37.5	0.870
	Whole	100.0	30 80	54.3	21 1	203.6	65.2	1.178

content of the whole fresh beans actually increases. There was very little difference between the thiamine content of the fall and summer crops.

The riboflavin content decreased with increasing maturity. The contribution by the pods was high at all stages. The fall crop contained about 25 per cent more of this vitamin at all stages of maturity.

The niacin content increased with maturity. The pods at all stages contributed a large fraction of this vitamin. The summer crop was a better source of this vitamin when harvested early.

CONCLUSION

These data indicate that green beans harvested in the most immature stage are highest in carotene and riboflavin but lower in thiamine and niacin than those harvested when more mature. Those harvested at commercial maturity are appreciably lower in carotene and a little lower in riboflavin. They contain about the same amount of ascorbic acid but are higher in thiamine and niacin. Beans used at the fresh shelled stages would be good sources of thiamine and niacin but very low in the other vitamins. Green snap beans harvested during mid-summer may contain more ascorbic acid and niacin, whereas those harvested in the fall may be higher in carotene and riboflavin. Green beans harvested as soon as the pods have reached full length will give maximum production and contain the best balance of vitamins.

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Variations in the Carotene Content of Carrots[1]

By ELMER HANSEN, *University of Oregon, Corvallis, Oregon*

THE data reported from several regions indicate that variations in the carotene content of carrots are related chiefly to variety (2), to stage of growth or development (5, 6, 8), and to the prevailing temperatures during the growing season (1, 5, 7). No information was available regarding the carotene content of carrots grown in Oregon or other Pacific Northwest States. The crop from this region, however, is an important item in the national supply; Oregon alone in 1944 producing approximately one-fifth of the total national canned pack as well as a significant portion of the tonnage used for quick freezing and dehydration. Investigations have been undertaken to study the effect of varietal and environmental factors on the carotene content of carrots grown in Oregon and preliminary data are presented.

METHODS

Twenty to thirty carrots were selected for uniformity in size; and after washing free of soil, three cross sections approximately 4 to 6 mm in thickness were cut from the crown, median and tip regions of each root. The sections were coarsely ground through a food chopper and thoroughly mixed. Duplicate 25 gm samples were transferred to 500-ml screw-cap bottles, covered with 200 ml portions of 95 per cent alcohol and stored at − 15 degrees C for periods not exceeding 72 hours. Carotene was determined by the method described elsewhere (3).

RESULTS

Changes in Carotene Content During Growth:—Chantenay carrots were planted at Corvallis in May and thinned to approximately 4 inches in the row. Samples were collected at 21-day intervals during the period extending from August 3 to December 5. Prior to sampling for carotene analysis, the average weights and crown diameters were determined.

According to the data (Fig. 1) carotene content (mg per 100 gm fresh weight) increased from 2.68 mg on August 3 to 10.31 mg on October 24 and 10.54 mg on December 5. Thus, the maximum carotene content was attained 20 weeks after planting, with no significant changes occurring thereafter. This final decline in rate of carotene accumulations may be correlated with lower mean temperatures during November and December. According to Magruder (5) the amount of carotene increases rapidly for the first 100 days and then more slowly, providing moisture and temperature conditions are favorable for its formation. Werner (8) found that the carotene in Chantenay and Nantes varieties grown in eastern Nebraska remained relatively constant after the maximum values had been attained. No

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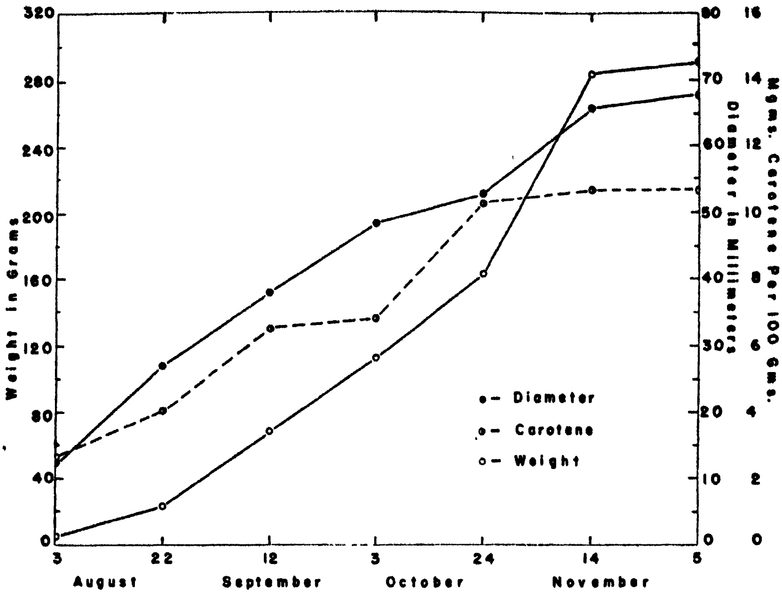

FIG. 1. Changes in the carotene content of Chantenay carrots during the growing season.

losses were observed even after 3 to 4 months' storage in damp sand at 38–40 degrees F.

The growth of the carrots as measured by increases in weight and crown diameter continued until November 14 and showed only slight gains thereafter. These results indicate that carrots have a definite stage of maturity with respect to maximum weight and carotene content and remain in an optimum condition for harvesting over a fairly long period.

Seasonal and Varietal Differences in Carotene Content:—Seven varieties of carrots were planted at Corvallis in May and collected for carotene analysis on October 18. A second planting was made in early August and samples of this crop were harvested in March. The data show (Table I) that the carrots grown during the winter season were much lower in carotene content than those grown during the summer

TABLE I—CAROTENE CONTENT OF SUMMER AND WINTER GROWN CARROTS

Variety	Mg Carotene/100 Gm	
	Summer	Winter
Imperator	14.00	3.64
Tendersweet	10.83	4.11
Chantenay	9.58	4.58
Scarlet Nantes	8.68	3.55
Nantes Coreless	8.57	3.04
Danvers Half Long	8.28	4.39
Goldinheart	8.23	4.58

and fall. No significant varietal differences were observed in the winter-grown crop, but Imperator was considerably higher in carotene than other varieties when grown to maturity during the summer and fall. Since alpha- and beta-carotene were not determined separately, the differences in total carotene values may not be of any great significance from the nutritional viewpoint. Harper and Zscheile (4) have shown that variations occur in both of these fractions, with the beta-carotene portion averaging approximately 54 per cent of the total carotenoids in 16 commercial varieties studied.

Carotene Content of Carrots Grown in Different Regions:—Chantenay and Danvers carrots were grown from the same source of seed in nine different areas within the state. These locations range in elevation from approximately sea level at Astoria to 4,200 feet at Burns, and differ greatly in soil and climatic conditions. Plantings made in June were harvested 16 to 18 weeks later. As shown by the data (Table II) no extreme variations were found in the carotene

TABLE II—CAROTENE CONTENT OF CARROTS GROWN IN DIFFERENT REGIONS

Location	Mg Carotene/100 Gm	
	Chantenay	Danvers
Burns	7.95	9.20
Corvallis	8.39	9.00
Astoria	8 39	8.10
Hood River	9.91	7 86
Union	8.69	6.78
Klamath Falls	7.77	6.48
Pendleton	7 51	—
Ontario	—	6.47
Medford	6.75	5.95

content of either variety grown in the various regions. It appears, however, that the carrots grown in the coastal areas as well as at the high elevations generally tended to be somewhat higher in carotene than those grown in the other regions. These differences may be associated with prevailing temperatures during the growing period, since maximum carotene development has been shown to occur at a temperature range of 60–70 degrees F (1, 5).

SUMMARY

Chantenay carrots grown during the period between June and December increased in carotene content from 2.68 mg to 10.31 mg per 100 gm during the first 20 weeks; but showed no significant changes thereafter. Growth as measured by increase in weight and diameter of crowns continued for approximately 3 weeks after maximum carotene content had been attained.

Winter-grown carrots were much lower in carotene content than those matured during the summer and fall. No significant varietal differences were observed in the winter-grown crop, but Imperator was higher in carotene content than six other varieties maturing during the summer and fall.

No extreme variations were found in the carotene content of two varieties of carrots grown in nine locations differing in elevation, soil and climatic conditions.

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Factors Related to Stem-end Shrink of the Sweet Potato[1]

By V. E. Hollar and E. S. Haber,[2] *Iowa Agricultural Experiment Station, Ames, Iowa*

There are approximately 3,000 acres devoted to commercial sweet potato production in southeastern Iowa, with about 20,000 additional acres of sandy soil which is suitable for sweet potato production. Sweet potatoes from southern states are shipped into Iowa each winter, while Iowa-grown sweet potatoes are shipped to Minnesota, North Dakota, and Wisconsin. These northern states prefer the Yellow Jersey variety because of its light-colored flesh which is relatively dry when cooked. Iowa consumers tend to prefer the varieties which are pink-to-orange in color and more moist when cooked. Iowa growers have been forced to grow the dry-fleshed Yellow Jersey because it is superior in keeping quality to the Big-Stem Jersey, a variety much more acceptable to the taste of Iowa consumers. The poor keeping quality of the Big-Stem Jersey, strains of which are locally known as "Prolific" and "Maryland Golden", has, therefore, forced the Iowa producers to relinquish markets in their own state to southern producers who ship in varieties, such as Porto Rico, which are moist-fleshed when cooked yet not susceptible to stem-end shrink. Aside from its tendency to develop stem-end shrink in storage, the Big-Stem Jersey is a highly desirable variety to grow because of its earliness and high yield. Because of the importance of this problem it seemed highly desirable to determine the nature of stem-end shrink and to attempt control measures.

Gradual shriveling of the proximal end may be noticed on an occasional sweet potato within a few weeks after the beginning of the storage period and as the season progresses it may be found on more and more potatoes and in greater severity. The exterior and interior of the stem-ends remain normal in color, and there is no suggestion of decay as described for the various known organisms which cause loss in storage. A casual observation might lead one to believe it a matter of water loss, but the tissue even in advanced shrink is flabby to the touch and does not become dry or hard as the storage season progresses.

Review of Literature

Stem-end shrink of the sweet potato was reported by Morgan (6) in 1938 to be the main cause of storage losses in Iowa. He described it as a non-pathogenic drying and shriveling of the stem-end particularly severe on the Prolific strain of the Big-Stem Jersey variety. He found that sweet potatoes grown without fertilizer suffered a mean loss in storage (rotting and shriveling were not separated) of 41.3 per cent, this figure being approximately double that of lots fertilized with 3–10–18.

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[1]Journal Paper No. J–1286, Project 300, Iowa Agricultural Experiment Station.

[2]The authors wish to acknowledge the assistance of W. E. Loomis and J. E. Sass of the Botany Department with the microscopic and physiological studies.

Erwin, Minges and Shepherd (3) in 1941 observed that application of fertilizer did not control stem-end shrink of the Big-Stem Jersey in Iowa. This statement was not necessarily contradictory to the experiments of Morgan as he did not claim complete control.

Elmer (2) recognized the importance of shriveling, which he described as a loss of water, in selecting varieties for storage. He observed that: "Common Big-Stem and Improved Big-Stem frequently shrivel excessively. This is especially true when the roots are stored in baskets or crates. Shriveling becomes more pronounced during some seasons than during others and it has been noted that shriveling becomes especially serious with roots that are harvested when they are comparatively immature."

Internal breakdown of the sweet potato was described by Artschwager (1) as a breakdown of the interstitial parenchyma resulting in hollows resembling in appearance the lysigenous air spaces found in stems, leaves, and roots of grasses and other plants. This condition does not in any way resemble stem-end shrink. Internal breakdown has more recently been described by Kimbrough and Bell (5) as a direct result of exposure to cold.

Harter and Weimer (4) in their exhaustive study of sweet potato diseases do not describe any condition, either pathological or physiological, which resembles stem-end shrink.

Experimental

Varietal susceptibility:—Nine bushel of each of three varieties, Porto Rico, Big-Stem Jersey or Prolific, and Yellow Jersey, were stored to determine varietal susceptibility. These were grown in replicated and randomized rows with 600 pounds per acre of 3–9–18 fertilizer applied to each. From each row in each replication, one bushel of U. S. grade No. 1 was harvested in October and placed in a local storage house until the following April. The temperature was 75 to 90 degrees F for 2 weeks of curing and thereafter it varied from 50 to 60 degrees F. The authors had no control over its management. In April each bushel was sorted and the number of potatoes having stem-end shrink was recorded.

The variety Porto Rico had no potatoes with stem-end shrink when it was examined in April. Yellow Jersey had an average of 0.78 shrunken roots per bushel, while Big-Stem Jersey had an average of seven potatoes per bushel showing various degrees of stem-end shrink. The average gain of Big-Stem Jersey over Yellow Jersey is 6.22 potatoes. The standard error being 0.97, the difference is highly significant. The potatoes in each variety were from 2 to 3 inches in diameter, and had been well fertilized and carefully stored, which may account for the relatively small number of shrunken potatoes as compared to the number observed in other seasons. A later experiment will show the importance of root size in susceptibility to shrink.

Wax emulsion dip:—The one bushel saved from each row in the foregoing experiment was not the total yield of each row, so it was possible to collect five bushels of Big-Stem Jersey variety from the replicated rows for use in the wax-dip experiment. Each bushel was

divided into five equal parts by count. The potatoes were variable in size from 1¾ to 3 inches in diameter, but by employing random selection in dividing the bushels the resulting groups were about equal. Each group contained 16 potatoes. Each of the groups from each bushel received one of the following treatments: (a) Completely dipped in wax emulsion; (b) 1 inch of the stem-end dipped; (c) 1 inch of the stem-end dipped, and the distal end cut off to leave a scar approximately the same size as the one normally left at the stem-end when the potato is removed from the vine; (d) the stem-end half of each potato dipped; (e) check. Results are presented in Table I.

TABLE I—PER CENT OF SWEET POTATOES DEVELOPING STEM-END SHRINK FOLLOWING WAX EMULSION TREATMENTS. AVERAGE OF FIVE REPLICATIONS

Treatment	Per Cent Having Stem-End Shrink After Storage
Whole potato dipped in wax emulsion	48.74
Proximal half of potato dipped	35.02
One inch of proximal end dipped	26.28
One inch of proximal end dipped and tip of distal end cut off	26.26
Check, no dip	23.78

Least significant differences
t.05 = 9.03
t.01 = 12 44

Cultural treatments:—The following cultural treatments were planted to determine the effect on stem-end shrink; (a) planting the rows on the level and applying the fertilizer as a side-dressing one month after planting; (b) planting the rows on a ridge, placing fertilizer beneath the ridge before planting, the usual method in Iowa; (c) planting on a ridge and applying the fertilizer 1 month later as a side dressing.

There were three replications of each treatment in a random block design, using the Big-Stem Jersey variety.

There were no significant differences in susceptibility to stem-end shrink in storage between the treatments.

Size of potatoes:—It had been observed that small sweet potatoes appeared to be more susceptible than large potatoes. Measurements taken on diameter and incidence of stem-end shrink showed differences that were highly significant. The mean diameter of the Big-Stem Jersey having stem-end shrink was 1.19 inches compared to 2.74 inches for a like number of sound potatoes selected at random from the same source. The mean difference was 0.947 inches with a standard error of 0.321 which was highly significant. It is a common practice among the growers to save small potatoes for "slip" production. Sprouts on slips do not arise from shrunken tissue. This must be taken into consideration in propagating.

Moisture percentage:—Four potatoes from 2 to 2.75 inches in diameter and an equal number of potatoes 1.5 inches in diameter from each of the three varieties were used. The mean moisture percentage from 10-gram samples taken at each end of each of these

potatoes is given in Table II, along with the difference between proximal and distal ends. This table is designed only to show the similarity between the two sizes of potatoes, commonly called "firsts" and "seconds". The difference between the two ends, or "proximal minus distal" in the table, was used to make the comparisons. The differences between sizes within varieties are 0.4, 0.6 and 1.6 per cent, respectively. These differences are not statistically significant. This lack of difference between large and small potatoes within a given variety permits the pooling of sizes. Table III shows the means from the eight potatoes of each variety, regardless of size. The difference between the proximal and distal end of Big-Stem Jersey, 5.7 per cent, is highly significant, as the standard error is 0.79. Yellow Jersey shows the same increase from distal to proximal end, the difference being 6.6 for this variety, the standard error 0.83, so the gain is highly significant. Porto Rico did not have a consistently greater percentage of moisture in the proximal end. The mean difference between ends was 0.3, the standard error 1.05, so the difference is not significant. Five of the eight Big-Stem Jerseys were visibly shrunken while the Yellow Jerseys were solid, so a difference in moisture percentage of the proximal ends of the two varieties might reasonably be expected. This difference did not exist, however, as there is only 0.9 per cent difference and the standard error is 1.08. The proximal end of Big-Stem Jersey had a mean moisture percentage of 71.7 compared to 65.1 per cent in Porto Rico. The difference, 6.6, is highly significant as the standard error is only 0.80.

TABLE II—MOISTURE PERCENTAGE OF TWO SIZES OF POTATOES FOLLOWING 3 MONTHS' STORAGE. AVERAGE OF FOUR POTATOES

Variety	Moisture (Per Cent)					
	2 to 2.75 Inches in Diam.			1.5 Inches in Diam.		
	Proximal End	Distal End	Prox Minus Distal	Proximal End	Distal End	Prox. Minus Distal
Big-Stem Jersey	71.8	65.9	5.9	71.6	66.1	5.5
Yellow Jersey	70.6	64.3	6.3	71.1	64.1	6.9
Porto Rico	66.6	65.6	1.0	64.5	65 1	−0.6

TABLE III—MOISTURE PERCENTAGE FOLLOWING 3 MONTHS OF STORAGE. AVERAGE OF EIGHT POTATOES

Variety	Moisture (Per Cent)		
	Proximal End	Distal End	Proximal Minus Distal
Big-Stem Jersey	71.7	66.0	5.7
Yellow Jersey	70.8	64.2	6.6
Porto Rico	65.1	65.4	−0.3

Big-Stem Jersey and Yellow Jersey each had over 5 per cent more moisture in the proximal than in the distal end, but there was no significant difference between the two varieties. Porto Rico had approximately the same moisture percentage at each end. Five of the

eight Big-Stem Jerseys used in the determinations were shrunken at the proximal end, still the moisture percentage was consistently greater at the shrunken end. This observation tends to substantiate the conclusion, originally made from the results of the wax-emulsion experiment, that moisture loss is not the cause of stem-end shrink of the sweet potato.

Periderm thickness:—Periderm thickness was measured in number of cells and in microns. An equal number of observations were made before and after curing. A comparison of the number of cells before and after curing is presented in Table IV.

TABLE IV—THICKNESS OF PERIDERM IN NUMBER OF CELLS BEFORE AND AFTER CURING. AVERAGE OF SIX POTATOES. AVERAGE OF TEN OBSERVATIONS ON EACH POSITION OF EACH POTATO

Treatment	Yellow Jersey			Big-Stem Jersey			Porto Rico		
	Prox. End	Center	Distal End	Prox. End	Center	Distal End	Prox. End	Center	Distal End
Before curing	4.67	5.17	5.00	4.17	4.17	4.83	4.00	3.17	4.00
After curing	4.67	4.67	5.83	4.17	4.33	4.67	4.67	5.00	4.33

Comparing "before curing" with "after curing", there is no significant difference between the means at any given position except the center of Porto Rico where the difference is highly significant. This is of no practical importance since stem-end shrink does not usually occur in this variety or in that position. Further microscopic studies in the thickness of the periderm in number of cells 1 month and 5 months after curing were made. Results are presented in Table V.

TABLE V—THICKNESS OF PERIDERM IN NUMBER OF CELLS 1 MONTH AND FIVE MONTHS AFTER CURING. MEAN OF THREE POSITIONS ON EACH OF THREE POTATOES*

Treatment	Yellow Jersey	Big-Stem Jersey	Porto Rico
1 month after curing	5.2	4.2	4.7
5 months after curing	4.9	4.6	4.7

*The potatoes used had not yet developed stem-end shrink.

The differences are not significant. Periderm cells did not disintegrate during the storage period (Fig. 1).

Immediately after curing, microscopic examinations were made of periderm thickness in the proximal end, center and distal end of six potatoes of the three varieties. Results are presented in Table VI.

TABLE VI—PERIDERM THICKNESS, AFTER CURING, IN MICRONS. MEAN OF SIX POTATOES OF EACH VARIETY

Variety	Position		
	Proximal End	Center	Distal End
Yellow Jersey	112	116	159
Big-Stem Jersey	103	108	116
Porto Rico	120	125	129

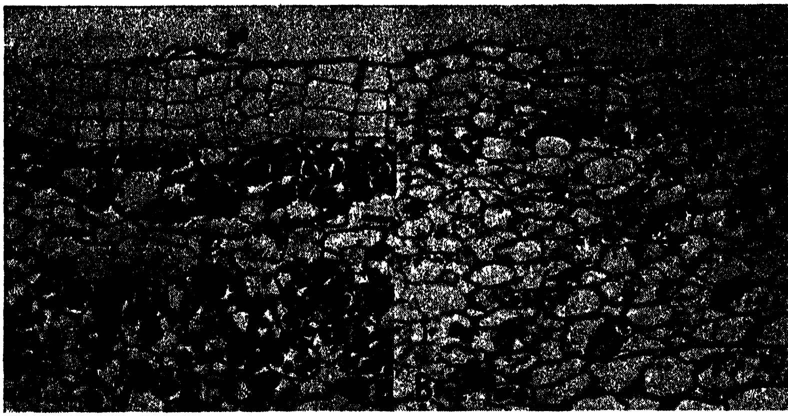

FIG. 1. Longitudinal sections of solid sweet potato tissue showing: (A) periderm after 1 month storage: (B) periderm after 5 months' storage. (90×) Periderm thickness in number of cells has not changed, but cell walls becoming irregular.

The periderm thickness was greater at the distal end of the Yellow Jersey than of the Porto Rico and Big-Stem Jersey, (Fig. 2) but this does not account for less shrink than Big-Stem Jersey as Porto Rico does not have this trouble and is not significantly different than the Big-Stem Jersey.

Measurements of periderm thickness 1 month and 5 months after curing were made. The means are an average of nine potatoes with 10 measurements on each position or region. Results are presented in Table VII.

TABLE VII—PERIDERM THICKNESS IN MICRONS 1 MONTH AND FIVE MONTHS AFTER CURING. POSITIONS OF SAMPLING POOLED

Variety	1 Month After Curing	5 Months After Curing
Yellow Jersey	149.2	107.5
Big-Stem Jersey	117.8	98.9
Porto Rico	139.3	103.0

This division is shown in Table VII in terms of the mean thickness of periderm of each variety 1 month and 5 months after curing. Positions of sampling have been pooled. Yellow Jersey periderm was 149.2 microns thick 1 month after curing, but only 107.5 after an additional 4 months. The mean difference is 41.7. The standard error is 9.85 so the difference is highly significant. The mean difference in the variety Big-Stem Jersey is 18.9, the standard error is 6.7, so the difference is significant at the 5 per cent level of probability. Porto Rico periderm decreased 36.1 units; the standard error is 8.2, so the difference is highly significant. This decrease in the thickness of each of the three varieties is the most noticeable discovery made during examination of the slides, but comparison of the varieties after the decrease shows no difference. Yellow Jersey had a mean thickness of

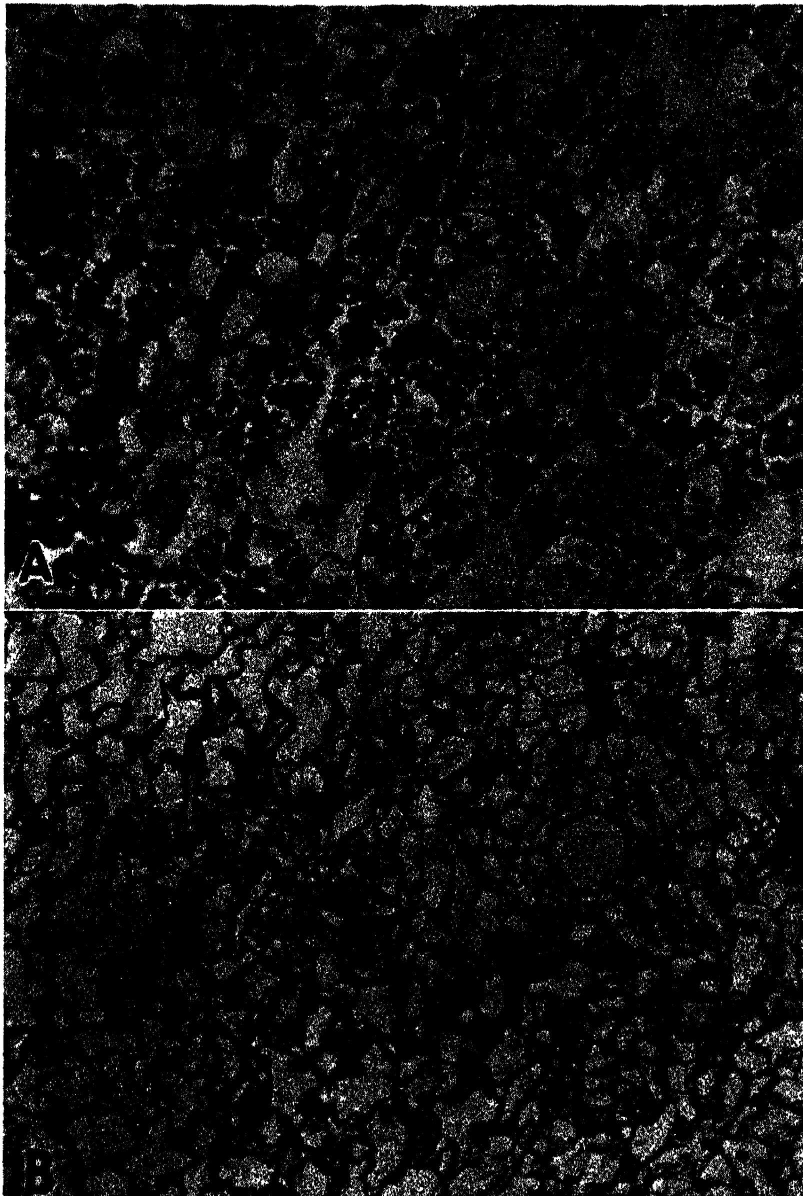

FIG. 2. Cross section of parenchyma from Big-Stem Jersey; (A) from solid tissue; (B) from severely shrunken proximal end. Cells are irregular in outline and contain very few starch granules in shrunken tissue.

108 microns, Big-Stem Jersey 99, and Porto Rico 103. The differences are not statistically significant.

Disappearance of starch and tissue collapse:—Notes on the relative abundance of starch granules in the parenchyma were taken from each slide examined during the periderm studies. Starch was generally present in abundance in tissue of sound potatoes, but there was either a noticeable loss or a complete lack of starch granules in parenchyma from proximal ends of severely shrunken roots. The irregular cell outline and collapsed condition of parenchyma generally found in severely shrunken proximal ends was associated with either marked reduction or a complete absence of starch granules.

Periderm of severely shrunken potatoes was badly torn, and individual cells were almost unrecognizable over severely-wrinkled and shrunken areas but the periderm cell walls continued to cling to the outer parenchyma (Fig. 3). This condition is definitely associated with stem-end shrink, but is believed to be a result, not a cause.

FIG. 3. Cross section of wrinkled tissue from end of Big-Stem Jersey showing collapsed periderm and parenchyma. Few starch granules are present. (Approximately 80×)

DISCUSSION

The susceptibility of Big-Stem Jersey and the resistance of Porto Rico and Yellow Jersey to stem-end shrink, proven experimentally, substantiate the general observations made over a period of 3 years. The average number of shrunken potatoes per bushel, (7), for Big-Stem Jersey was sufficient to show the difference among varieties,

but should not be taken to represent the usual amount of shrink in field run or mixed size lots. Roots less than 2 inches in diameter were not included in the variety comparison. It has been observed that in Big-Stem Jersey potatoes in commercial bin storage sometimes it is difficult to find a single root not shrunken at the proximal end. This is more nearly a rule than an exception where small roots are saved for seed. From a group of Big-Stem Jerseys of mixed size (field run), the average difference between sound and shrunken roots was approximately 1 inch in diameter.

One of the theories advanced by growers is that the high temperature near the top of a ridge affects the uppermost ends of Big-Stem Jersey in some way. It was thought that planting on the level was more satisfactory than ridge planting for this reason. There was found to be no difference between these two methods, however. A late application of fertilizer also failed to change the tendency to shrink in storage.

Certain wax emulsions have been used commercially and experimentally to lessen shrinkage from water loss in many fruits and vegetables. Platenius (7) found Brytene 333–B, the wax emulsion used in the experiment reported herein, to be valuable in checking shrinkage with 13 vegetables, including beets, carrots, rutabagas, snap beans, squash, and pumpkins. The fact that Brytene 333–B increased the number of sweet potatoes developing stem-end shrink is a very important clue to the nature of the shrink. It does not conclusively prove that stem-end shrink of Big-Stem Jersey is not a matter of water loss, but does suggest that the trouble is one of breakdown of solids, aggravated in this experiment by an upset of the gas exchange balance.

The number of layers of cells in the periderm of Yellow Jersey, Big-Stem Jersey and Porto Rico was the same after curing as it was before, except in the center position of Porto Rico. At this position the periderm was very thin before curing, but became as thick as in other positions after curing. It seems highly improbable that this condition is in any way connected with the good keeping quality of Porto Rico. A comparison of the proximal ends of the three varieties either before or after curing show no difference in number of cells of the periderm. The centers also were equal after storage, but cell number was greater in the distal end of Yellow Jersey than in either of the other varieties. Porto Rico was about the same as Big-Stem Jersey. We therefore have a position of one of the three varieties which is outstanding for its thickness in number of cells. Had this increase occurred at the proximal end of both of the good-keeping varieties, it would have been considered as a probable factor, but as it occurred at only the distal end of one variety and did not extend as far as the center, it seems likely that it is of no significance. The possibility of its being a factor seems even less, when examination of the periderm at all positions 5 months after curing shows the average thickness to be the same for all three varieties.

Measurement of the periderm thickness in microns gave results the same as cell-number counts, except that a definite decrease in the

actual depth of periderm occurred between 1 and 5 months of storage. The breaking down of periderm cells, although not an answer to stem-end shrink, is an interesting problem in itself. The cause of the reduced thickness of periderm, while the number of cells remains practically the same, is readily seen to be the bending or breaking of many of the "end" walls of the periderm cells. These walls, perpendicular to the longitudinal axis of the potato, often appear zig-zag in longitudinal sections taken after 5 months' storage. This flattening of the periderm between 1 and 5 months after storage was uniform for all varieties and positions studied.

The absence of starch granules in severely shrunken tissue was fairly obvious, while no lack of starch could be found consistently in other tissue. It was difficult, however, to distinguish between regions of high and low starch content from a simple observation of the granules. A critical study of starch content should be made to supplement the microscopic observations.

The first stage of stem-end shrink is represented by a slight flabbiness of the tissue, and here it is difficult to find a lack of starch by microscopic means, although it is thought that a deficiency is beginning to occur. There is no apparent collapse of periderm or of storage cells at this early stage, and it is only in wrinkled or severely shrunken tissue that collapsed cells are found. The collapse of parenchyma cells is definitely correlated with a visible disappearance or reduction of starch granules, although a few granules may often be observed in collapsed cells. The collapse is not accompanied by a breaking of cell walls, but appears more like a result of slow shrinking such as might be expected when the contents of a cell are reduced. The breakdown of periderm cells does not follow this pattern, however, as they are empty and non-living. The change in outline of the periphery of the potato results in formation of sharp angles which the periderm is not able to follow without rupture of cell walls. It has also been shown that periderm cell walls are in a poor condition even over sound cells in lower tissues, after 5 months' storage. Having already started to break apart, the strain of movement would seem to be especially disastrous, and it is easy to imagine how the individual periderm cells have arrived at their condition, in which they are almost unrecognizable.

Regardless of the cause of stem-end shrink, the condition of the periderm in shrunken potatoes would suggest that moisture might be lost more rapidly than from solid potatoes. A comparison of moisture percentages after 3 months of storage, at which time five of the eight Big-Stem Jerseys had shrunken proximal ends, showed an average of 5.7 per cent more moisture in the proximal than in the distal ends. A similar difference in favor of the stem-end was found for the Yellow Jersey, which had no shrunken potatoes at that date. These data indicate strongly that stem-end shrink is not caused by moisture loss. If the relatively high percentage of moisture is an indication of a loss of solids, then solids must be lost from the proximal end of Yellow Jersey also, which does not usually shrink. Further investigation is necessary to show why these two varieties of the Jersey group behave

differently in storage. Porto Rico, also a non-shrinking variety, showed no difference in moisture percentage between ends. Its moisture percentage was approximately the same as in the distal ends of Yellow Jersey and Big-Stem Jersey.

CONCLUSIONS

1. Big-Stem Jersey is more susceptible to stem-end shrink than Yellow Jersey and Porto Rico.
2. Small potatoes are more subject to stem-end shrink than large potatoes.
3. Cultural practices, ridge vs. level culture, have no influence on the incidence of stem-end shrink.
4. Fertilizing heavily does not prevent stem-end shrink.
5. Wax emulsion caused an increase in the percentage of potatoes developing shrink.
6. Periderm thickness was the same at the ends of all three varieties studied. Yellow Jersey and Porto Rico, good keeping varieties, have no more periderm protection in number of cells or thickness at the ends than Big-Stem Jersey, a susceptible variety.
7. Starch decreases in the parenchyma cells as stem-end shrink develops.
8. Moisture is as great or greater in shrunken tissue as in sound tissue.

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A Comparison of the Number of Protoxylem Strands With the Rotenone Content of Derris Roots[1]

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Derris elliptica (Wall.) is a perennial leguminous vine cultivated for its roots which contain the important insecticide, rotenone (5). Derris grown wild in the forest often has less than 2 per cent rotenone but selected clones sometimes contain 10 per cent or more (7). The problem of recognizing inferior plants at an early stage of growth becomes important in a breeding program involving a large progeny; otherwise, each seedling requires two years in the field before it can be evaluated. This paper presents results from the first of a series of studies made in an attempt to identify anatomical characteristics in roots which might be correlated with high or low rotenone content.

Worsley and Nutman (8) found that the first cells in derris roots to contain rotenone were longitudinal bands of parenchymatous tissue in the phloem. These bands of cells were invariably arranged opposite to the protoxylem strands and were of corresponding number. (A similar arrangement was noted in the study presented here.) They also found that later rotenone deposition occurred in scattered cells of the xylem but particularly in the rays of parenchyma tissue which develop radially from the protoxylem strands as secondary thickening occurs. This information would suggest a possible correlation between the number of protoxylem strands in derris roots and their rotenone content at the time of harvest.

The numbers of protoxylem strands in roots are known to vary among adventitious roots and also among laterals (2, 3). Therefore, a relatively wide variation might be expected in the roots of derris, which is ordinarily propagated by stem cuttings. A primary question to be settled in this study was whether the frequency of occurrence of different numbers of protoxylem strands is characteristic of a given variety.

Ten leafless stem cuttings 8 inches in length of each of the four varieties[2] available at this station were rooted in sand. The Changi No. 3 from Río Piedras and the St. Croix varieties usually produce less than 3 per cent rotenone, the Sarawak Creeping about 5 per cent cent rotenone, and Clone 73 of Changi No. 3 more than 8 per cent rotenone. Within four weeks roots over 6 inches in length developed

[1]The author acknowledges assistance of Mrs. Aida G. Villafañe in making many of the anatomical observations.

[2]Sarawak Creeping is a well-known variety introduced from the Far East and St. Croix is from a seedling of Sarawak Creeping grown in the Virgin Islands. Changi No. 3 from Río Piedras was introduced from the Far East through the Agricultural Experiment Station of the University of Puerto Rico at Río Piedras. Clone 73 of Changi No. 3 came from the Goodyear Rubber Plantations Company, Gatun, Panama, and was introduced there from the Far East. Clone 23 of Changi No. 3 used in a later experiment came from the same source.

from the cuttings and they were removed for study. The technique employed to observe the number of protoxylem strands in a root consisted of making a fresh cross section with a straight-edge razor, rinsing in water, and staining momentarily in safranin. This stain emphasized the more lignified tissues such as the protoxylem strands. From 38 to 60 roots of each variety (a total of 193) were observed to have a minimum of 4 or maximum of 8 protoxylem strands as shown in Fig. 1.

Chi-square analysis of a contingency arrangement of the data showed the number of protoxylem strands in roots of Changi No. 3 from Río Piedras was less by high significance than the other three

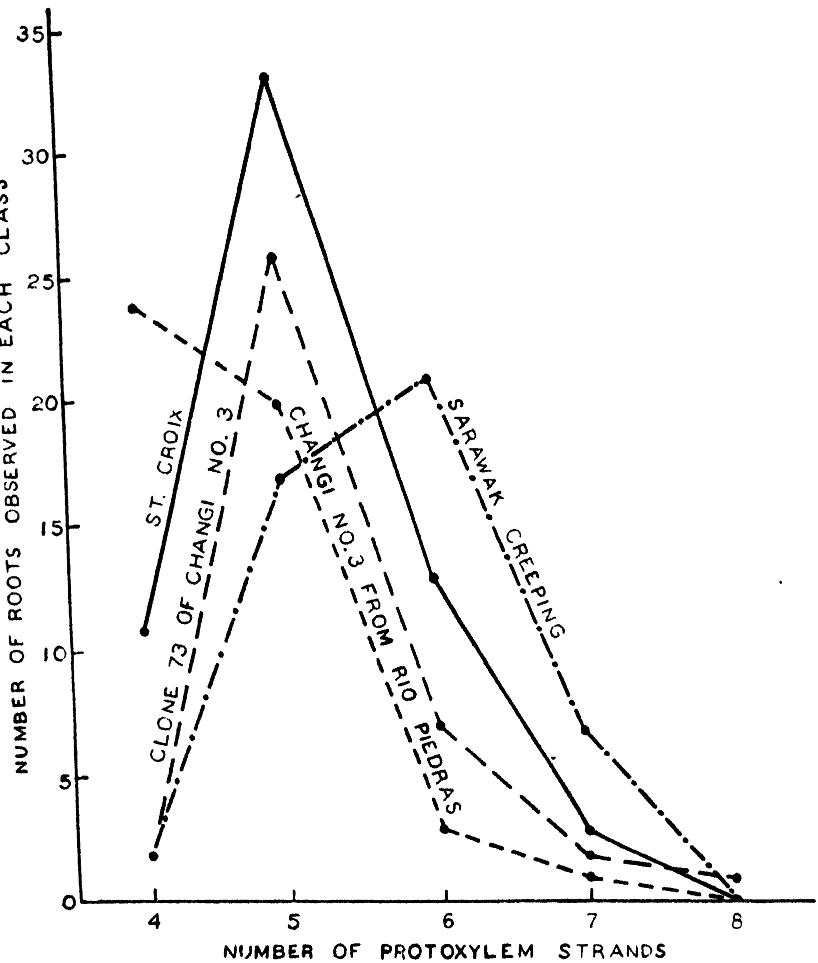

FIG. 1. Frequency of different numbers of protoxylem strands in adventitious roots of four varieties of *Derris elliptica* (Wall.) Benth. The numbers of protoxylem strands were characteristic for the variety, but were not correlated with rotenone contents.

varieties. Conversely, the number of protoxylem strands in roots of Sarawak Creeping was greater by high significance than the other three varieties. Roots of St. Croix and Clone 73 of Changi No. 3 had medium numbers of protoxylem strands as compared with the other two varieties studied. Therefore, the frequencies of different numbers of protoxylem strands appear to be varietal characteristics. However, there was no correlation between the frequency of certain numbers of protoxylem strands in a variety and the percentage of rotenone the variety usually produces.

A second experiment was performed with the roots from the only available mature (3 years) plant of Clone 23 of Changi No. 3 which had shown an average of 9.29 per cent rotenone in a portion of its roots sampled the year previously. The root system was removed as completely as possible and brought to the laboratory where nine comparable roots of pencil-size diameter were chosen for study. Four of these roots had 4 protoxylem strands, three had 5 strands, and two had 6 strands. The longer roots, 75 to 140 cm, were divided into distal, middle, and proximal sections for chemical analyses,[3] making a total of 21 samples. Red-color values (4) determined for each sample showed as much, and sometimes more, variation in the rotenone content within a single root than between roots. Therefore, it was not possible to correlate the rotenone content of these roots with the number of protoxylem strands. Unpublished data at this station have demonstrated that large variations in rotenone content within a single root is of common occurrence and, therefore, further sampling was not done for this study. Apparently the total rotenone deposition in mature roots is not associated with the number of protoxylem strands to a measurable extent.

A third experiment involved the study of protoxylem strands in roots developed from cuttings grown in soil in V-shaped boxes with glass sides similar to a method used previously (1). After measuring the daily rate of root elongation against the glass sides for 30 days, 54 roots were excavated and classified as having 4, 5, 6, or 7 protoxylem strands. There was a chance of correlation between the rate of root elongation and the number of protoxylem strands. The average daily rate of root elongation expressed on the basis of a single root was 0.38 cm for Changi No. 3, 0.45 cm for Sarawak Creeping, and 0.52 cm for St. Croix. However, so much variation in the rate of root elongation occurred within any one class of protoxylem strands that no correlation could be established. It was evident, therefore, that factors other than the number of protoxylem strands were associated with the rate of root elongation from these cuttings.

Cuttings of Clone 73 of Changi No. 3 rooted in sand were observed to develop a significantly greater number of roots in the quarter of the stem circumference, which included the basal bud. Therefore, 38 roots were classified as having arisen from near the basal bud, opposite the basal bud, or from either side of the cutting. The number of protoxylem strands in the roots ranged from 4 to 8 but there were

[3]Appreciation is expressed to Merriam A. Jones, chemist at this station, for the chemical analyses.

no consistent differences between groups. It was concluded that the origin of roots from stem cuttings in relation to the basal bud was not associated with their number of protoxylem strands.

The rotenone content of large samples of derris roots has been found to be associated with the diameter size of the roots (6). In general, roots 4–8 mm. in diameter have the greatest percentage of rotenone. Eames and MacDaniels (2) state that "... in some pines, for instance, the vigorous and main roots are tetrarch, the others diarch; .... ". If a similar correlation between size of roots and number of protoxylem strands were found to exist in derris, the observation would have practical value. In this experiment a study was made of the protoxylem strands from three mature plants of St. Croix. Forty older roots, near the region of the original cuttings, were separated into three classes according to diameter: 0.1 to 0.3 cm, 0.8 to 0.9 cm, and 1.5 to 2.2 cm. No consistent differences in numbers of protoxylem strands of roots in the three classes occurred in the observations made. Therefore, the diameters of derris roots from mature plants were concluded not to be associated with the number of protoxylem strands.

Summary

A study was made to determine if there is a relationship between the number of protoxylem strands in derris roots and the amount of rotenone deposited.

The average numbers of protoxylem strands in roots of Sarawak Creeping, St. Croix, Changi No. 3 from Río Piedras, and Clone 73 of Changi No. 3 were found to be varietal characteristics.

The rotenone content of individual roots or of varieties could not be correlated with the number of protoxylem strands.

No correlation existed between the daily average rate of root elongation and the number of protoxylem strands.

No consistent differences in numbers of protoxylem strands were found in roots arising in the region of the basal node near the bud, opposite the bud, or from either side of stem cuttings.

No correlation existed between the diameter of roots from mature plants and the number of protoxylem strands.

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Further Comparative Studies of Varieties of Certain Fruits and Vegetables for Dehydration

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An earlier report having a similar title (1) summarized findings obtained in studies in this laboratory on the comparative suitability for dehydration of groups of varieties of some of the more important vegetables, including sweet corn, potatoes, sweet potatoes, onions, and green beans. The work is being actively continued and extended to other vegetables in the hope that it may ultimately serve as an inventory, for each of the more important vegetables, of the varieties that are best suited to preservation by drying. It is believed that such information is of value not only in the immediate emergency but also as a foundation for a permanent dehydration industry after the return of peace.

The results obtained in work carried out in the season of 1943, in so far as they relate to the comparative quality of varieties, are summarized here. Details of technique of preparation and drying are largely omitted as of minor interest for the present purpose; they are fully stated in more complete papers dealing with each of the vegetables or fruits, to which reference is made herein for the convenience of those interested.

Results with Highbush Blueberries

Fruit of 14 of the more important commercial varieties of highbush blueberries (2) was obtained from commercial plantings near Hammonton and Pemberton, New Jersey, transported by motor truck to the laboratory at Beltsville, Maryland, and stored at 40 degrees F for 3 or 4 days prior to use in the work. The fruit was dehydrated, without any preparatory treatment other than thorough washing, on wire mesh trays in an air current of 550 feet per minute at a temperature of 140–145 degrees F. Drying was terminated when the fruit had a residual moisture of approximately 15 per cent. Drying was very slow but the temperature used could not be increased above 150 degrees without injury, and attempts to partially remove the waxy coating and "check" the skins by the use of a lye dip were abandoned because of injury to the material.

The dried material of the various varieties differed considerably in attractiveness, partially because of variation in uniformity and depth of color, and partially because of differences in size and manner of shrinkage in drying. Atlantic, Stanley, Dunfee, and Jersey were among the most attractive in the dry condition; Adams, Cabot, Rancocas, and Rubel were least attractive. Rubel, Adams, and Jersey gave exceptionally high yields, one pound of dry fruit (of 15 per cent moisture content) from 5 to 5.4 pounds fresh fruit; Cabot, Dunfee, and Sam were lowest, yielding one pound dry fruit from 6.2 pounds fresh. The general average for all varieties was one pound from 5.7 pounds fresh.

The dry material was tested for comparative palatability and quality by refreshing, preparing, and serving to the judges as dessert fruit and in the form of pies, and, in some varieties, as muffins.

The amounts of water absorbed in refreshing and cooking were greatest in June, Atlantic, and Stanley, least in Harding and Rancocas, but in no case exceeded half that lost in the drying. The fruits consequently remained more or less flattened and wrinkled, but were agreeably tender and melting. Color and general appearance very closely resembled the cooked product from fresh material of the same varieties.

The cooked material was graded both unsweetened and after sweetening by addition of 15 per cent by weight of sugar. The effect of sweetening was that the scores on flavor were somewhat improved for the more acid berries, while those for less acid varieties were correspondingly reduced. All factors considered, Atlantic, Jersey, and Katherine were much superior to the others; Pemberton, Rubel, and Sam were slightly below the first group; and the remaining varieties, Adams, Cabot, Concord, Dunfee, Harding, June, Rancocas, and Stanley, were satisfactory but not outstanding in quality. When made up into pies or muffins, the presence of the pastry very largely masked distinguishing varietal differences with the result that judges found it hard to determine their preferences. Concord received the highest score in the pies, with Atlantic, Cabot, Dunfee, and Jersey following in the order named.

Results with Freestone Peaches

The results of a study of varietal suitability for dehydration in Eastern freestone peaches (3) made as a part of an investigation of the possibilities for making satisfactory canned, preserved, or dehydrated products from these fruits, is summarized as to its varietal findings elsewhere in this volume p. 241. Of 61 varieties, nearly all yellow, melting-fleshed, freestone types, the peeled, dehydrated products of 3 were rated as excellent, 17 as very good, 10 as good, 15 as fair or acceptable, and 16 as poor to very poor. When dried without peeling, most of the material was mediocre or poor, only 15 varieties receiving a rating of good, none as very good or excellent.

Results with White Potatoes

The earlier study (4) of late or main-crop potatoes grown in some of the Northern producing districts was continued and completed by collection and dehydration of material of the early crop grown by cooperators in the National Potato Breeding Project in Texas, Florida, Louisiana, South Carolina, Virginia, Maryland, New Jersey, and California (5). Each of the cooperators supplied the varieties that are of greatest commercial importance as early-crop varieties in his state. Irish Cobbler and Katahdin were each represented by material from five states, Chippewa by material from four, Triumph and Sebago each from three, White Rose from two, and seven less widely grown varieties by material from a single state each. The potatoes

from each district were dug at the time of commercial harvest in that district, but, in addition, harvesting of portions of the plots was delayed, in the case of the varieties grown at certain stations, until the tops had died down, usually for about 2 weeks. Twenty-seven lots dug at commercial harvest and also seven from delayed digging were used in the work. The digging dates for the various districts ranged from May 20 to August 25, each lot being immediately shipped by express to Beltsville and dehydrated within 2 or 3 days after its arrival. The technique of preparation and drying was uniform throughout and conformed to approved practice.

Data obtained for the fresh material included apparent degree of maturity, range in size of tubers, specific gravity of large and small tubers, and percentages of loss in peeling and trimming. For the dry product it included yields as percentages of whole and of peeled, trimmed stock, color and general appearance, and amount of water absorbed in refreshing and cooking. The cooked products, prepared as riced or "mashed" potato, without any seasoning or other additions that might mask differences in flavor, were scored separately on the factors color, texture or consistency, and palatability and flavor, these separate scores then being averaged to give a final rating for each sample.

The physiological immaturity of the commercial-harvest samples from all the districts was shown by the small size of tubers, the fraying and loosening of peels, the low specific gravities (ranging from 1.035 to 1.078 but falling below 1.060 in the great majority of samples), and the low yields of dry product. The delayed-harvest samples from the same plots had larger size, higher specific gravity, lower preparation losses, and larger dry yields. There was a wide range in dry yields calculated as percentages of peeled, trimmed stock, with extremes of 15.1 and 25.3 per cent but with the majority of the samples between 17 and 20 per cent. There was consistent correlation between specific gravity of the fresh potatoes and the dry yields. There was also very consistent correlation between specific gravity of the fresh potatoes and the final grade on quality of the cooked product, for the reason that as specific gravity increased, there was improvement in consistency and mealiness, color, and flavor of the cooked material.

None of the 34 lots of early-crop potatoes yielded a product rated as of highest excellence in quality. Thirteen were rated good to very good; the remaining 21 from good through fair or acceptable, to poor. The higher ratings were widely distributed with respect to both variety and place of growth, as was the case with the lower scores, and were correlated with degree of maturity of the sample rather than with variety or district.

In all of the material, a yellowish coloration affecting uniformly all parts of the sample became apparent shortly after drying was begun and increased until drying was completed. It varied in intensity with variety and especially with degree of maturity of the sample, being most pronounced in the most immature lots. It was entirely distinct from the discolorations due to tyrosinase reaction, accumulation of

sugar due to prolonged storage at low temperatures, or imperfect washing after lye-peeling. It was found to be due to the presence of carotenoids, which have been found present in traces in all varieties of potatoes thus far examined (22 in number) in amounts roughly paralleling the intensity of the yellow tint of the dehydrated product. The color due to the presence of carotenoids is not very intense in the dehydrated product made of fully mature potatoes, but a greater intensity of color is quite evident in that made from stock of low total solids and starch content. The low yields and only fair quality of the dehydrated products made from immature potatoes show clearly that such material is undesirable for the purpose of dehydration and that stock intended for such use should be allowed to become fully mature before harvesting.

Results with Beets

Dehydrated beets are now being produced in very considerable quantities in the United States, the requirements for the period July 1, 1944, to June 30, 1945, having been stated as 8,630,000 pounds of dry product, that for the year July 1, 1945, to June 30, 1946, as 7,711,000 pounds. These quantities are approximately equivalent to 32,000 and 29,700 tons of fresh beets. As information in regard to the quality of the product obtainable from the various varieties is fragmentary and conflicting and no comparative studies of groups of varieties grown and dehydrated under controlled conditions had been made, such a comparative study was undertaken in the season of 1943 (6). Twenty-seven varieties of red garden beets, with three varieties of mangel-wurzel and one of sugar beet, were grown together at the Plant Industry Station, Beltsville, Maryland, in a planting made on July 22. Rainfall was exceptionally low up to mid-September and several irrigations were necessary prior to that time. Conditions later in the season were very favorable and all varieties made fair-to-good, although not heavy, yields. They were harvested Nov. 9–11, 110 days from date of planting, and held in common storage about 3 weeks before being dehydrated.

In the dry material, there was intensification and darkening of color and almost complete disappearance of zoning, with the result that many or most of the varietal samples were indistinguishable in color and general appearance.

When refreshed and cooked after storage in air at 70 degrees F for 2 months, the great majority of the varieties regained approximately 80 per cent of the water originally present in the fresh material, and the form of the pieces was very well restored. Refreshing and cooking were accompanied by a general lightening of color to very nearly that of the fresh material except that zoning was practically obliterated by spreading of color from the darker zones. There was a very striking degree of uniformity in color and attractiveness of the cooked samples. Texture was, in the great majority of the samples, very good to excellent, but a few were slightly tough as a result of imperfect rehydration. Flavor was only very slightly affected by dry-

ing, and the range in its intensity and quality with different varieties was about that found in the fresh material.

Factors considered in comparing and grading the cooked samples were: Completeness of refreshing, color and general attractiveness, texture, and naturalness and agreeableness of flavor. The range of differences in quality and acceptability was slight, all the samples being quite acceptable, but the varieties were divided into three groups on the basis of over-all averages of the grades on all factors considered, as follows:

Highest Excellence: Asgrow Wonder, Burpee Extra Early, Detroit Dark Red, Detroit Perfected, Early Red Chief, Edmand's Improved Blood Turnip, Improved Blood, Improved Early Blood, Holmes' Green Top, Long Season, Half Long Blood (Market Gardeners), Ohio Canner, Perfected Detroit Dark Red Turnip, and Short Top Detroit.

Good to Very Good: Boston Crosby, Crosby Egyptian, Crimson Globe, Crimson King, Early Wonder (Model), Eclipse, Extra Early Dark Beauty, Gurney's Early Model Globe, Henderson's Special Crosby Egyptian, Fireball, Improved Long Dark Blood, and Perfected Early Wonder.

Fair or Acceptable: Long Smooth Blood Red, the sugar beet U. S. 215 x 216, and the three mangel-wurzels, Golden Tankard, Mammoth Golden Giant, and Mammoth Long Red.

In selecting varieties to be grown for dehydrating purposes, many factors not taken into consideration in the grading of the material for quality, such as size, productiveness, adaptation to climatic and soil conditions, degree of resistance to locally prevalent diseases, and the like, would have to be taken into account. In the present material, average weight per root ranged with variety from 111 grams to 405 grams in red beets and up to 907 grams in one of the mangels, yields of dried product varied more than 150 per cent, and total solids content varied from 15.2 to 22.8 per cent. Some of the small-sized, low-yielding varieties obviously would have no commercial possibilities. The present results emphasize the fact that when grown under favorable conditions as a fall crop and harvested before becoming overgrown and fibrous, the various varieties of red garden beets do not differ greatly in inherent quality and palatability and make very good to excellent dehydrated products.

Storage of dehydrated material of 5 to 5.5 per cent moisture content in air and in CO_2 at 70 degrees F for 14 months has resulted in slight lowering of palatability and flavor in the the lots stored in air, with little or no change in quality in those in CO_2. Dehydrated beets withstand storage in air a little less well than sweet corn and sweet potatoes, but much better than white potatoes, carrots, and pumpkin.

Results with Carrots

Production of dehydrated carrots in 1943 totalled 32,000,000 pounds; in 1944, 30,100,000 pounds; and requirements for 1945 are placed at 13,265,000 pounds. These amounts are approximately equiv-

alent to 192,000, 121,000, and 79,600 tons, respectively, of the fresh vegetable. Every phase of the preparation and dehydration of the carrot and of its subsequent packaging and storage has been the subject of intensive investigation, but comparatively little attention has been given to study of the comparative suitability for drying purposes of the various varieties. The varietal material thus far used has consequently been determined by the quantities of the different varieties available rather than by selection of varieties known to be best suited to the purpose.

Thirty varieties and strains of orange-fleshed carrots, including all those sufficiently widely grown to be of any commercial importance, were grown at the Plant Industry Station, Beltsville, Maryland, in a planting made July 22 and harvested Nov. 9, 110 days from date of planting (7).

Data obtained from study of the fresh material included average weight per root, specific gravity and total solids content, color of cortex and core by matching with the Maerz and Paul color standards, and ascorbic acid and carotene content. The average weight per root was 112 grams with extremes of 62 and 157 grams. The range of specific gravity was from 1.014 to 1.039 with most varieties falling in the range 1.020 to 1.030. Extremes in total solids were 11.79 and 14.62 per cent, with the majority of the varieties falling within the range 12.2 to 13.6 per cent. Specific gravity and total solids content were very closely correlated. Ascorbic acid averaged 5.8 mg. per 100 grams fresh weight with extremes of 3.31 and 9.63 mg.; carotene averaged 9.44 mg. with extremes of 6.89 and 12.26 mg. Yields of dry product as percentages of the fresh weight ranged between 6.5 and 9.9 per cent but most varieties was between 7.5 and 8.5 per cent. Losses in peeling and trimming, which averaged 23 per cent but ranged between 13.4 and 30 per cent with size and shape of roots, had more effect in determining dry yields than did total solids content.

The material was refreshed, cooked, and scored after a period of 70–75 days in storage in CO_2 in sealed containers at 70 degrees F. The percentage of water absorbed in refreshing and cooking ranged between 400 and 542 per cent but was for the great majority of samples between 425 and 475 per cent. The amount of water absorbed apparently bore no relation to variety, total solids content, or the preparatory treatment given before drying.

Factors taken into consideration in grading the reconstituted cooked samples included naturalness and attractiveness of color, degree of discoloration (darkening or fading), completeness of refreshing, texture, and fullness and naturalness of flavor. The width of range in quality and desirability was not great, all varieties being acceptable. Those ranking as Best were Amsterdam Forcing, California Bunching, Goldinhart, Imperator, Improved Chantenay, Morse Bunching, Nantes, Nantes Half Long, Oregon Chantenay, Oxheart, Perfection, Tendersweet, and Touchon. Those classed as Very Good were California Peerless, Corneli Coreless, Early Golden Ball, Hutchinson, Improved Danvers Half Long, Long Type Chantenay, and Red Cored Chantenay. Those ranked as Fair were Chantenay Coreless,

Danvers Special, Improved Long Orange, Streamliner, and Supreme Half Long. Differences in flavor were not large, and the natural fresh flavor was very well preserved. All varieties were free of woodiness and toughness and were rated good-to-excellent in texture. By reason of the rather narrow range in scores on flavor and texture, the degree of uniformity of color and freedom from fading or darkening played a predominant part in determining the ranking given the various varieties. Preservation of original fresh color, both in the dry material and in the refreshed and cooked material, was in all cases better in samples given a brief dip into dilute sulphur dioxide solution prior to blanching and drying, and the retention of carotene after 20 weeks storage in CO_2 at 70 degrees F was also considerably better in the lots so treated than in unsulfured checks. Retention of carotene in lots stored at 50 degrees F in CO_2 was materially higher than in duplicate samples stored at 70 degrees F in CO_2. Loses of ascorbic acid in blanching and drying were rather large in all cases but were slightly greater in lots dipped into SO_2 solution prior to blanching than in checks blanched without such treatment.

Results with Green or Snap Beans

The preliminary study of dehydration of green beans previously reported (8) has been repeated and expanded, employing 42 varieties and strains of which 32 were bush and 10 were pole types (9). Thirty-two of the number were widely grown commercial varieties, including nearly all that are of importance and general distribution in the Eastern United States, while ten were unnamed selections developed in the bean breeding work of the Division of Fruit and Vegetable Crops and Diseases. All the varieties were grown together on a plot of Congaree silt loam at the Plant Industry Station, Beltsville, Maryland, in a planting made on July 15, 1943. The season was an exceptionally hot, dry one and several irrigations were necessary throughout the season. All the varieties made satisfactory growth and gave fair-to-heavy yields. A few varieties not well adapted to the conditions, especially Blue Lake and Pioneer, set pods only after the establishment of cool weather, but were bearing well when defoliated by frost on October 18. All varieties were exceptionally free of disease and the crops as a whole was of fine quality and considerably better than that with which the preliminary work of the previous year was done. The crop was harvested under almost ideal conditions in the period Sept. 17-Oct. 20. As the temperatures in the period in which pods were developing was low, development of fiber in the side walls of the pods was at a minimum.

The various types and varieties differed so widely in size, shape, and weight of pod that mechanical sorting by size or weight was inapplicable and it was necessary to devise some other method of determining and defining the various stages of development. The method adopted was that of arbitrarily dividing the whole period of development and usable maturity of the pod into stages on the basis of the relative proportions by weight of seed and pericarp making up the pod. In the first stages, seeds made up to 1 to 3 per cent of the

weight of the pod, in the second, 3 to 5 per cent, and in the subsequent stages 6 to 10, 11 to 15, 16 to 20, 21 to 25, and more than 25 per cent of the total pod weight. Samples of different varieties in which the seeds made up a like proportion of the weight of the pod were considered to be at a comparable stage of development regardless of differences in shape or size of pods. Bulk samples of several bushels of a variety were sorted by hand into several lots differing in their stage of development and these were prepared and dehydrated separately after portions of each had been removed for determination of moisture and ascorbic acid content and of the percentages of seed and pericarp. The dried material of each variety consequently consisted of four to six samples differing in their stages of development and collectively representing the entire period of usable maturity of the green pod. The material intended for use in the varietal comparisons for quality of dehydrated product was prepared and dried by a standardized routine procedure; other portions of the same material were subjected to a considerable variety of preparatory treatments designed to preserve color or prevent destruction of flavor and vitamin content during dehydration or subsequent storage.

The dry material was stored in air at a temperature of 70 to 75 degrees F for 14 weeks prior to examination. The refreshed, cooked samples of each variety at each of the several stages of maturity were separately compared and scored on flavor, texture, and color, the final score for the variety being obtained by averaging all the individual scores. The varieties were grouped into four classes on the basis of their comparative quality as dehydrated products. Those rated as First Rank or Excellent were Asgrow Stringless Green Pod, Burpee Stringless Green Pod, Giant Stringless Green Pod, Landreth Stringless Green Pod, Lazy Wife, Tendergreen, and the unnamed selections 1194A, 1194B, 1194D, and 1194E. Those of Second Rank, Good-to-Very-Good, were Blue Lake, Dwarf Horticultural, French Horticultural, Full Measure, White Rust Resistant Kentucky Wonder, White Seeded Kentucky Wonder (Burgers Stringless Green Pod), Stringless Red Valentine, U. S. No. 5 Refugee, Keeney's Stringless Green Refugee, and the selections 1194C, 1196F, 1197G, and 1197H. Those of Third Rank, Fair or Acceptable, were Asgrow Stringless Black Valentine, Ideal Market, Kentucky Wonder, Brown Rust Resistant Kentucky Wonder, U. S. No. 8 Kentucky Wonder, U. S. No. 9 Kentucky Wonder, Longfellow, Pioneer, Refugee (Thousand-to-One), and Tennessee Green Pod. Those of Fourth Rank, Poor and Definitely Unsuitable, were Bountiful, Stringless Kidney Wax, Improved Stringless Kidney Wax, Pencil Pod Wax, Plentiful, Streamliner, and Unrivalled Wax.

Ascorbic acid content in any given variety varied with the stage of development, its amount per unit of weight being lowest in very young "baby" beans and increasing rather rapidly up to the point at which seeds constituted 11 to 15 per cent of the pod weight, after which increase became slow or ceased. The varieties were divisible into three groups on the basis of their ascorbic acid content at the stage of optimum condition for use (seeds making up to 11 to 15 per

cent of the pod weight). Each of the three groups contained varieties of all the various types and of widely varying quality. The high group had ascorbic acid content ranging between 30 and 41 mg per 100 grams; it included Dwarf Horticultural, French Horticultural, Keeney's Improved Stringless Kidney Wax, Lazy Wife, Stringless Red Valentine, Streamliner, Unrivalled Wax, and 1194A. The medium group, with 20 to 30 mg per 100 grams was made up of Asgrow Black Valentine, Bountiful, Stringless Kidney Wax, Longfellow, Pencil Pod Wax, Pioneer, Plentiful, Refugee (Thousand-to-One), Kenney's Stringless Green Refugee, Asgrow Stringless Green Pod, Burpee Stringless Green Pod, Giant Stringless Green Pod, Landreth Stringless Green Pod, Tennessee Green Pod, 1194D, 1194E, and 1197H. The remaining varieties had amounts of ascorbic acid ranging from 19.8 mg down to 7.86 mg per 100 grams. In a few of this last group, the amounts present continued to increase beyond the stage of development chosen for use in the comparisons.

The routine steam blanch employed detroyed 40 to 45 per cent of the ascorbic acid content of the material and a further loss in drying brought the total destruction to approximately 90 per cent. Dry material stored 6 months in air at 70–75 degrees F and then refreshed and cooked in most cases retained a considerable proportion of the amount found immediately after drying. Dipping the prepared material into dilute solutions of sodium chloride, sodium bicarbonate, sulfite of sodium or of potassium, or sodium thiosulfate prior to steam blanching did not materially decrease the destruction of ascorbic acid during steaming and drying. Dipping into a solution of sulfur dioxide in water or exposing to sulfur dioxide as the gas, had some protective effect, reducing the loss during steaming and drying to 68 to 75 per cent. All treatments that introduced SO_2 into the material prior to drying prevented discoloration and gave better preservation of original color than occurred in check tests.

Dehydrated green beans are much more resistant to deterioration when stored in air than most other vegetables. Material stored in air in closely woven cloth bags for 38 weeks retained good flavor with only slight darkening in color, and was still acceptable after 55 weeks of such storage. Check lots in sealed glass jars stored at 70 degrees F were very good in color and flavor after 55 weeks.

Results with Pumpkin and Winter Squash

Twenty-one varieties of winter squash, *Cucurbita maxima*, and twenty-one varieties of pumpkin, twelve of *C. pepo* and nine of *C. moschata*, were grown for use in the work (10). They were harvested Oct. 15, 120 days from the date of planting, and dehydrated within a few days to 3 weeks after harvesting. Studies made on the fresh material in the field and laboratory included determination of trueness to name, yields, average weight of fruits, thickness and hardness of shell, color of flesh, total solids, vitamin content, and percentage of loss in peeling and preparation. Losses in peeling vary enormously with variety accordingly as the character of the shell does or does not

permit lye-peeling. A considerable variety of preparatory treatments were used with each variety; these included drying raw, precooking in steam, sulfuring or dipping into solution of sodium sulfite, potassium sulfite, sodium chloride, or sodium bicarbonate. Drying was uniformly begun at 160 degrees F and finished at 140 degrees. The dry products were at once packed in sealed containers, a portion of each lot in carbon dioxide and the remainder in air, and stored at 70 degrees for 4 months prior to cooking and grading.

Total solids were highest in the squashes *(C. maxima)* intermediate in *C. pepo,* and lowest in *C. moschata,* the extremes being 20.76 per cent in Delicious and 5.52 per cent in Connecticut Field. There were correspondingly wide differences in yields of dry product. Ascorbic acid content varied widely with variety, from 32.3 mg per 100 grams in Delicious to 2.48 mg in Golden Cushaw, more than half the varieties having amounts in excess of 10 mg. There was a rather consistent positive correlation between ascorbic acid and total solids content.

The refreshed, cooked material was first graded on the factors of color and general appearance, completeness of refreshing, naturalness and attractiveness of flavor, and texture or consistency, and the separate scores on these factors were summed up in a final rating on comparative desirability. Those ranking as Best or of Highest Excellence were Banquet, Golden Delicious, Mammoth Chili, Buttercup, Boston Marrow, Sibley, Banana (both orange and gray types), and Long Island Cheese. Those classed as Intermediate, or Fair-to-Good, were Arikara, Blue Hubbard, Cheese, Cheyenne, Delicata, Dakota, Delicious, Dickinson, Early Sugar, Essex Hybrid, Green Striped Cushaw, Golden Hubbard, Mammoth (King of the Mammoths), Omaha, Tennessee Sweet Potato, Quality, Warren, White Cushaw, Wisconsin Canner, and Winter Luxury. Those ranking Low or Poor were Connecticut Field, Fordhook Bush, Fort Berthold, Golden Cushaw, Royal Acorn, Virginia Mammoth, Japanese Pie, True Hubbard, Kitchenette, Table Queen, Mammoth Table Queen, and Chicago Warted Hubbard.

As a further test of quality of the material, pies were made up from it and graded for color and appearance and eating quality. Presence of the pastry, milk, and seasoning had a masking effect upon differences of flavor that had been apparent in the unseasoned cooked products and many samples were given higher ratings in the form of pies than they had received in unseasoned form. This was especially the case with varieties, such as the Hubbards, having considerable green color at the surface and extending into the flesh. The darkening of this color in drying and subsequent refreshing and cooking made the material unattractive in appearance as compared with the clear yellows of other varieties. When made into pies, the greenish tint of the material was largely lost, becoming merged into the brown considered desirable in a pie. Consequently, the varieties containing green color, in pie form, received scores more nearly corresponding with their predominantly good-to-very-good ratings on flavor and texture. The very great majority of the varieties made pies which were entirely acceptable to very good in quality and flavor, although

not quite equal to those made from fresh material of the same varieties.

When examined after 4 months' storage the series of samples dried raw were poorest of all in appearance and quality, having faded or darkened and lost flavor and most of their carotene content. Those dipped into sodium chloride or sodium bicarbonate solution prior to blanching were also poorer in color and flavor and in retention of carotene than those given the routine steam blanching. Exposure to fumes of sulfur or dipping into sulfite solution prior to blanching gave better preservation of color and of carotene than the routine steam blanch alone.

Carotene content of the dry material of the series dried by the routine method was determined after 4 months' storage in CO_2 at 70 degrees F. It differed enormously with variety, from 38.7 mg per 100 grams dry material in Dickinson to 0.89 gram in Fordhook Bush. Thirteen varieties had 10 mg or more, ten of them belonging to *C. maxima,* the remaining three to *C. moschata.* Of ten varieties having amounts between 9.88 and 5.83 mg, seven belong to *C. maxima,* one to *C. moschata,* two to *C. pepo.* Of the remaining 14 with amounts ranging from 4.52 to 0.89 mg two belong to *C. maxima,* two to *C. moschata,* the remaining ten to *C. pepo.* There was a rather consistent relationship between apparent depth or intensity of yellow color of flesh and the carotene content retained by the variety.

In the ranking of the varieties as to quality, such factors as productiveness, ease of preparation, and yield of dry product per unit of fresh were not considered. The assemblage of varieties here used show such tremendous differences in all these respects that they must be taken into account in deciding upon the varieties that are best for drying. When the factors of productiveness, ease and convenience of peeling and preparation, dry matter content (which is closely correlated with yield of dry product), color, table quality, content of vitamins A and C, and keeping quality of the dehydrated product are so considered, the fifteen varieties ranking highest in desirability for dehydrating purposes are, in descending order: Golden Delicious, Boston Marrow, Banana, Virginia Mammoth, Long Island Cheese, Mammoth Chili, Mammoth (King of the Mammoths), Cheese, Dickinson, Banana (Orange Type), Early Sugar, Connecticut Field, Golden Cushaw, Wisconsin Canner, and Golden Hubbard.

Discussion

Comparative study of the dehydrated products of groups of varieties of the various vegetables emphasizes the enormous differences between the various vegetables as respects the range of differences in quality found in their generally cultivated varieties. In the red garden beets here studied, there was a very narrow range in palatability and flavor and a similarity in these respects which made many of them indistinguishable one from another to taste. There was an almost equal degree of uniformity in basic quality and desirability in most of the orange-fleshed carrots used in that study. In the work with sweet corn (11) it was pointed out that when comparison was made at the optimum stage for use, the differences in palatability and desirability

as food products between about three-fourths of the group of 34 varieties were very small or negligible. In white potatoes assembled from various producing districts, there was a rather wide range in quality of product but most of this was the consequence of variations within varieties resulting from lack of adaptation to the conditions of the various districts in which they were grown. All varieties were capable of attaining high table quality in those producing districts to which they were well adapted. In all of these vegetables, breeders have concentrated upon the production of varieties having high palatability and appealing flavor, and have been so far successful that varietal material not having these characters has been largely eliminated from cultivation. In green beans, other considerations than inherent high quality and palatability, such as productivity and market appearance, have had weight in determining survival of varieties and the assemblage of varieties used in the work showed a very wide range in quality and appeal as food. In sweet potatoes (1) and in the pumpkin and squash group (10) the assemblages of varieties that are in more or less general cultivation represent the whole range of possibilities in inherent good quality and palate appeal, from excellent through mediocre to extremely poor. Comparisons of the dehydrated products eliminate a considerable number of varieties as being without possibilities for the purpose, because such comparisons emphasize the basic deficiencies in quality of the raw material.

Prolonged storage experiments under a variety of conditions show that the various dehydrated vegetables differ greatly in their resistance to deterioration in appearance and palatability when stored under identical conditions. Of the vegetables thus far studied, sweet corn and sweet potatoes rank highest in their resistance to deterioration. Beets and green beans are about equal in their resistance, which is somewhat less than that of sweet potatoes and corn. Both are distinctly more resistant than white potatoes, which are, in turn, more resistant than pumpkin and squash. Carrots show very little resistance, becoming poor to inedible more quickly than any of the other vegetables named when held under identical storage conditions.

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Flower Initiation and Development in the Orchid Cattleya Pinole

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ABSTRACT

This paper had been published in full in the *Bimonthly Bulletin* of the Ohio Experiment Station.

IN Cattleya pinole, flower bud formation does not occur in shoots less than 8 centimeters long. Between a length of 12 centimeters and 18 centimeters the flower primordia are formed. Flower parts are distinct when the flower bud is 2 millimeters long. This section is also of interest as it indicates that abortion of the upper two buds may have occurred in this early stage of development. The first month's growth is the critical stage which determines whether the shoot may flower. The second month's growth is the period of flower bud initiation and will determine the number of flower buds formed.

Inheritance in Begonia Semperflorens

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Bateson and Sutton (1), working with hybrid types of tuberous rooted begonias, were unable to determine the method of inheritance of doubleness. When they crossed the single Begonia Davisii on double-flowered plants, the progeny was all double. However, B. Davisii fertilized with its own pollen gave all singles. This led to their conclusion that with B. Davisii doubleness was linked to the male side. They found conflicting evidence of sex-linkage in other begonias with which they worked.

To ascertain the method of inheritance of doubleness and other characters in Begonia semperflorens, work was initiated at the University of New Hampshire[1], the results and discussion of which follow.

I. Preliminary Genetic Studies

Doubleness:—In four separate crosses made between double and single parents the F_1 populations were single, showing doubleness to be recessive. The segregation of these hybrids in the F_2 is shown in Table I.

TABLE I—F_2 Populations Involving Doubleness

Parents	Total Number	Single		Semi-double		Double	
		Number	Per Cent	Number	Per Cent	Number	Per Cent
Double × Red Single	344	274	79.6	47	13.7	23	6.7
Double × White Single	508	472	92.2	9	1.8	27	5.3
Double × B. semperflorens Calla	197	187	95.0	10	5.0	0	—
Semi-double × B. subvillosa	380	320	84.2	60	15.8	0	—

The F_2 from the cross double X red single gave approximately 13 singles, 2 semi-doubles and 1 double. In a similar cross which involved the same double and a white single line, approximately the same percentage of doubles appeared in the F_2, but more singles and almost no semi-doubles. This and later progenies from this white flowered line show that some factor is linked with the white color which inhibits the appearance of semi-doubleness. The counts on an F_2 population of double X B. semperflorens Calla may have been altered by lethal factors involved that caused albino seedlings. The semi-double parent that was crossed with B. subvillosa was pure for semi-doubleness and the F_2 progeny fit a 13:3 ratio, the doubleness being replaced by semi-doubleness.

One dominant factor S causes singleness even when present in the heterozygous form. When this factor is present as the double reces-

[1]Peter Moorenovich, a student in horticulture at the University of New Hampshire from 1941–1943, made the first and some of the other crosses involved in this work.

sive ss, other factors causing semi-doubleness or doubleness may make their appearance.

TABLE II—F_1 SINGLE BACKCROSSED TO DOUBLES

Parents	Total Number	Single		Semi-double		Double	
		Number	Per Cent	Number	Per Cent	Number	Per Cent
Geneva Rose × F. red	625	341	54.5	161	25.5	123	20.0
Geneva Scarlet × F. red	640	364	56.7	139	21.9	137	21.4

The same F_1 single backcrossed to two different doubles gave a ratio of 9 singles, 4 semi-doubles and 3 doubles.

TABLE III—DOUBLES X SEMI-DOUBLES

Parents	Total Number	Single		Semi-double		Double	
		Number	Per Cent	Number	Per Cent	Number	Per Cent
41-17 × 41-20	153	—	——	69	45.0	84	55.0
Geneva Rose × Semi-double	119	21	17.6	53	42.4	45	40.0
Red Double × Semi-double	83	—	——	45	54.0	38	46.0
Double × 43-4	70	—	——	34	48.6	36	51.4
Double × 43-11(1)	198	—	——	115	58.1	83	41.9
Double × 43-11(2)	59	—	——	35	59.3	24	40.7

Crosses between doubles and semi-doubles for the most part fit 9:7, 7:9 or 1:1 ratios. In only one of such crosses made have singles appeared among the progeny. A number of different ratios could be derived from Table III. Genotypically there are several different semi-doubles and the same may be true of doubles.

TABLE IV—PROGENIES OF SEMI-DOUBLES SELFED

Parents	Total Number	Single		Semi-double		Double	
		Number	Per Cent	Number	Per Cent	Number	Per Cent
41-20	200	26	13.0	139	69.5	35	17.5
41-10	187	0	——	187	100.0	0	——
41X	208	0	——	150	72.0	58	28.0
43-11	198	89	44 8	71	36.0	38	19.2
43-4	139	57	41.0	56	40.3	26	18.1
41-12	82	9	11.0	60	73.2	13	15.8

From the progeny counts obtained by selfing semi-doubles, Table IV, apparently there are at least four different semi-doubles as follows: those containing approximately (a), 100 per cent semi-doubleness; (b), 72 per cent semi-doubleness and 28 per cent doubleness; (c), 72 per cent semi-doubleness, 17 per cent doubleness, and 11 per cent singleness; and (d), 40 per cent semi-doubleness, 20 per cent doubleness, and 40 per cent singleness.

This partially explains the variety of results obtained when doubles were crossed with semi-doubles. There is a wide variation in the appearance of semi-doubles, Fig. 1, but this alone is not a satisfactory indication of the amount of doubleness they carry. Temperature, available food, time of year and perhaps other factors contribute to the

FIG. 1. Semi-doubles that vary from near singles to near doubles appear in the F_2.

degree of doubleness of this semi-double group. White semi-doubles were less double in appearance than colored ones, further substantiating the theory that some inhibitor is linked with white color.

To determine whether sex-linkage enters into the inheritance of doubleness in these begonias, reciprocal crosses were made, the results of which are shown in Table V. From these data there is no evidence that doubleness is sex-linked.

TABLE V—RECIPROCAL CROSSES INVOLVING DOUBLENESS

Parents	Total Number	Single		Semi-double		Double	
		Number	Per Cent	Number	Per Cent	Number	Per Cent
(41-20) × (Double × Calla) F_1	106	64	60.4	33	31.1	9	8.5
(Double × Calla) F_1 × (41-20)	174	101	58.0	56	32.2	17	9.8

Early Vigor in Seedlings Influences Percentage of Doubleness:—Begonia seedlings from two unrelated crosses between doubles and semi-doubles were separated into large and small plants at the time of transplanting, 2½ months after seeding. The weakest plants were grown along in community flats until large enough for spacing. The large and small plants bloomed at about the same time and were the

same size at that stage. Table VI shows the percentage of doubles and semi-doubles in these populations.

With this material there was a considerably higher percentage of doubles among the plants that were more vigorous in the seedling stage. If this is true with other begonia crosses, it could account for some of the lack of uniformity in progeny counts in Tables III and IV, since not all seedlings were grown to maturity in every case.

TABLE VI—SEEDLING VIGOR AND DOUBLENESS

	Semi-doubles		Doubles	
	Number	Per Cent	Number	Per Cent
Population Number 1				
Large	33	41.8	46	58.2
Small	30	58.8	21	41.2
Population Number 2				
Large	8	47.1	9	52.9
Small	10	76.9	3	23.1

Flower Color:—Three different crosses were made between red and white, the resulting F_1 populations being a uniform medium pink. The F_2 populations from these crosses segregated into red, all gradations of pink and white. Red was difficult to separate from dark pinks and some of the whites, especially the singles, were not distinct from the lightest pinks. Table VII gives the counts on the three F_2 populations which are all subject to considerable error in color classification. The whites in the F_2 population from red X B. subvillosa (white) were classified the most accurately, since there were no pale trace pinks in this group. This population indicates three factors for color, with white being the triple recessive.

Red X white $(\text{semperflorens})_A$ and red (Calla) X white represent the first counts made for color, before any accurate method of color classification was devised. The reds in these counts included some dark pinks and the whites included all the trace pinks. Later it was noted that the trace pinks could be distinguished from whites by the pigment present in the unopen buds. Reds may be separated from darkest pinks by allowing them to open fully.

A later count from this same cross, red X white $(\text{semperflorens})_B$, is much more accurate and gives a ratio of 1 red, 14 pinks of all gradations, and 1 white. In this instance the evidence points to two color factors, with white the double recessive and red perhaps the homozygous dominant.

TABLE VII—F_2 POPULATIONS FOR COLOR

Parents	Red		Pink		White	
	Number	Per Cent	Number	Per Cent	Number	Per Cent
Red × White (semperflorens) A	65	12.8	343	67.5	100	19.7
Red (Calla) × White	22	12.0	104	56.5	58	31.5
Red × White (subvillosa)	109	28.7	264	69.5	7	1.8
Red × White (semperflorens) B	18	8.7	177	85.5	12	5.8

In backcrossing the various shades of pink on pure reds or whites, they were described as dark pink, medium pink (the shade obtained when white is crossed with red), light pink, and trace pink, the latter having just a tint of pigment on the ovary of female flowers and in the center of double flowers.

TABLE VIII—BACKCROSSES FOR COLOR

Parents	Red		Pink		White	
	Number	Per Cent	Number	Per Cent	Number	Per Cent
Red (1) × Medium Pink......	110	50.0	110	50.0	—	—
Red (2) × Medium Pink....	52	43.7	67	56.3	—	—
Red × Trace Pink (43-4).....	33	47.1	37	52.9	—	—
White × Trace Pink (43-4)....	—	—	54*	56.8	41	43.2
White × Trace Pink (43-11)...	—	—	41*	43.2	54	56.8

When the Chi Square test is applied to the backcross progenies in Table VIII, all of them could fit a 1 : 1 ratio. This would indicate that there is one factor difference between red and pink, or trace pink and white. When trace pink was crossed on red the color of the progeny was the same as that obtained from red X medium pink.

To determine the genetic make-up of some of the lighter selections from the F_2 population these were selfed by caging and their progeny counted, Table IX. The light pink selection produced two distinct lots of progeny — the pinks being the same color as their parent. Trace pink selection 43–4 produced several gradations of pinks, while selection 43–11 produced uniform trace pinks and whites.

TABLE IX—F_2 SELECTIONS SELFED

Parents	Red		Pink		White	
	Number	Per Cent	Number	Per Cent	Number	Per Cent
Light Pink B.	—	—	22	57.9	16	42.1
Trace Pink (43-4)	—	—	139	100.0	—	—
Trace Pink (43-11)*....	—	—	27	71.0	11	29.0
White B_1	—	—	—	—	106	100.0

*To obtain highest accuracy only the doubles were counted. The slightest tint of color shows in the central petals of doubles, but may be missed in singles.

To definitely establish the method of inheritance of flower color in begonias, additional self pollination and crossing between pure lines will have to be done. The evidence presented here points to two or three factors that determine color.

Foliage Color:—Four F_1 populations have been obtained by crossing Carmen, a dark red-leaved variety on various green-leaved varieties. The dark foliage color is dominant, the F_1 being as dark in color as Carmen. Considerable sterility has been encountered with the F_1 plants, but 156 seedlings have been raised to maturity from four different hybrids. Approximately 50 per cent of the F_2 progeny have dark foliage, 25 per cent are intermediate, and 25 per cent are green.

When the variegated Begonia semperflorens var. Calla, Fig. 2, was

FIG. 2. *Begonia semperflorens* Var. Calla.

crossed on two different green-leaved varieties, the F_1's were green. In one case the F_2 population segregated into 164 green and 24 mottled; in the other F_2, there were 247 green, 90 mottled and 13 calla or variegated. When selfed, two mottled plants from the first F_2 population produced 106 mottled, 4 calla, and 41 mottled, 0 calla, respectively.

When selfed, the Calla begonia produces green and calla plants in the ratio of about 1 : 1, together with varying numbers of albino seedlings. Since this variegation in the Calla begonia often causes albino seedlings in its progeny, the counts may be subject to considerable error. The calla formation is inherited, hence it can be combined with other characters such as flower color or doubleness.

Plant Habit:—It was noted that many of the populations of begonias segregated for plant habit. Two distinct habits noted were upright and well branched as shown in Fig. 3. Plants pure for these characters were crossed, the resulting F_1 begin upright. A backcross of the F_1 on the branched or recessive gave 25 upright and 28 branched. A different backcross made at a later date produced 15 upright and 15 branched. A plant püre for the upright character when crossed with an F_1 upright, produced all upright progeny. Self pollination of an F_2 branched selection produced all branched progeny From these data, branching is recessive to upright with the relationship monogenic.

FIG. 3. Branching versus upright habit.

II. Hybrid Seed Production

When crosses between doubles and semi-doubles eliminated the singles and gave a high percentage of doubles in the progeny, the possibility of producing doubles from seed was suggested. These hybrid seedlings are insect and disease free and much more vigorous than clonal stocks. A number of male and female parents have been tested for this seed production. Hybrid seed distributed to begonia growers has given excellent results.

In producing hybrid seed, careful selection of the parents is essential. Both parents should be dwarf, well-branched, and free blooming and pure for the color selected. The female parent must be double-flowered and produce normal female flowers during the seed production period which usually does not include winter. Some double-flowered plants produce female flowers with deformed petals in the place of stigmas, hence they are of no value in seed production. The male parent should be a semi-double that produces pollen well and transmits a high percentage of doubleness to its progeny. Although doubles may be more desirable, even the semi-doubles are usually more salable than singles.

Unless some insect can be found that will cross pollinate these begonias efficiently, the pollinating must be done by hand. Weights of cleaned seed per pod of this hybrid seed have averaged 8–11 mg. At the current price of domestically produced double petunia seed, which

is comparable, each seed pod would be worth 20 to 30 cents. At this price the cost of hand pollination would not be prohibitive.

The female flowers on double begonias are in a lateral position so are sometimes choked off if all the terminal double flowers are allowed to mature. The removal of one to three of the clusters of five or more double flowers as soon as they start spreading apart will allow the female flowers to develop. It is well to leave one of the outside double flowers to each female flower, at least until the female is pollinated. If all the doubles are removed early, the female flowers often abort.

To produce red hybrids, both parents must be pure line reds.

To produce white, both parents must be pure line whites.

Pink may be obtained by crossing a pure red and a pure white.

To introduce 100 per cent dark foliage into the hybrids, one of the parents must be pure for this factor.

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Inheritance in the Carnation. V. Tetraploid Carnations from Interspecific Hybridization

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Although the presentday carnation is available in a greater range of colors than any other species of *Dianthus* it does not possess the attractive color patterns present in some of the forms of *D. chinensis*, notably those of *D. chinensis* var. *Heddewigii*. If by means of hybridization some of these patterns could be transferred to the carnation the result might well be something worthwhile. Though the results obtained so far have not reached this goal, they have nevertheless proved interesting and profitable, in that a race of promising tetraploid carnations has developed. The purpose of this report is to describe these results.

Materials and Methods

Seed of commercial varieties of *D. caryophyllus*, *D. chinensis*, and *D. chinensis* var. *Heddewigii* was obtained in 1936 and 1937 from some of the leading seed growers. The seeds were germinated in the greenhouse in the Spring of 1938 and the young plants were transferred to the field as soon as they were large enough to transplant. A few plants from each accession were grown in the greenhouse during the Summer of 1938 and, from each group, five plants were selected for chromosome counts. *Dianthus* species are difficult cytological material because of the small size of the chromosomes and their failure to stain well with the stains ordinarily used in temporary smears. Therefore, all counts were made on permanent preparations stained with crystal violet and safranin according to Stockwell's schedule (1934). The results are summarized in Table I.

As soon as the plants came into flower crosses were made between the different species and varieties. All the plants used in the crosses were also self pollinated.

Experimental Results

The direction of the crosses made little difference. In the *chinensis-caryophyllus* crosses an abundance of seed was obtained either way, although somewhat less seed was obtained when the carnation was used as the seed parent. So far as the direction of the crosses is concerned, the same was true of *chinensis-Heddewigii* and *Heddewigii-caryophyllus* crosses, but the seed yield was much less. Sixteen crosses between *D. chinensis* and *D. Heddewigii* yielded less than 50 seeds which produced seven hybrids. Of these, four were tetraploid and highly fertile, and three were triploid and sterile. The three triploids and one tetraploid were obtained from crosses in one direction and

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TABLE I—CHROMOSOME COUNTS OF CARNATION MATERIAL

Variety	Species Complex	Number of Accessions	Chromosome Number 2_n
Giant Perpetual *carnation	*Caryophyllus*	3	30**
Chabauds carnation	*Caryophyllus*	3	30
Enfant de Nice carnation	*Caryophyllus*	3	30
Marguerite carnation	*Caryophyllus*	3	30
Grenadin carnation	*Caryophyllus*	1	30
D. chinensis	*Chinensis*	3	60
D. Heddewigii	*Chinensis*	3	30
D. Heddewigii var. *laciniatus*	*Chinensis*	3	30

*These were obtained from seedsmen. Many clones and seedlings of the Greenhouse type have also been examined. All of these have been diploid $2_n = 30$ except for occasional tetraploid root tips.
**A few tetraploid root tips, $2_n = 60$, were found in this group.

three tetraploids from crosses in the other. From 10 crosses between *D. Heddewigii* and *D. caryophyllus* only five seeds were obtained which produced 2 diploid hybrids, both of which were highly sterile.

It should be pointed out that although Regel in 1858, according to Bailey (4), designated *D. Heddewigii* and *D. laciniatus* as varieties of *D. chinensis,* the trade generally has offered *Heddewigii* as an independent species and *laciniatus* as a variety of *D. Heddewigii.* The results obtained here support this division of the species for, if *Heddewigii* is only a variety of *D. chinensis,* though different in chromosome number, it should not have been any more difficult to obtain hybrids between them than between the diploid *D. caryophyllus* and the tetraploid *D. chinensis.* Also, it should have been relatively easy to obtain hybrids between *D. caryophyllus* and *D. Heddewigii.* However, since the crosses which involve *D. Heddewigii* have had no part in the production of the tetraploid race of carnations which it is the purpose of this paper to describe, they will be discussed separately at a later date. Accordingly the present discussion will be confined to the hybrids of *D. chinensis* and *D. caryophyllus.*

Altogether 18 crosses were made between these species yielding a little over 800 seeds. Several different types of carnations were used but most of the crosses involved the perpetual flowering or greenhouse carnation. Ten seeds of each cross were planted and gave a total progeny of 163 plants. When these came into flower one unusual plant was noted (Number 38131–1). This plant was glaucous, like the carnation parent, and essentially intermediate between the parents, while all the others were green, like *D. chinensis,* and on the whole much more like this parent. It was a bushier plant than its sister seedlings and came into flower about two weeks later (fig 1B). It eventually attained a greater size than its sister seedlings and flowered profusely with self-colored pale magenta flowers. The other seedlings produced flowers of a more reddish hue and some had the color pattern peculiar to *D. chinensis.* Where semi-double carnations were used as parents about half the progeny were semi-double.

Examination of the pollen showed that the unusual plant had uniformly good pollen of approximately twice the volume of carnation pollen. (Fig. 2C). All the other seedlings had very poor pollen. Chromosome counts made on 20 plants showed this unusual plant to be tetraploid and all the others to be triploid.

Curiously, this tetraploid plant came from a cross in which a mutant type of carnation known as *thin* (1) had been used as the seed parent (Fig. 1C). This type is worthless for commercial purposes and the only reason for using it as a parent was to ascertain

FIG. 1. (A) *Dianthus chinensis*, 2n = 60. (B) Tetraploid F_1 hybrid, 2n = 60. (C) *Thin* and normal diploid carnation, 2n = 30. (D) Upper left, seeds of *Dianthus chinensis;* upper right, seeds of carnation; upper middle, F_1 seeds (note larger seed in lower left of group); lower middle, seeds from tetraploid F_1. (E) Four plants of first back-cross to carnation, the two plants on the left are triploids, those on the right are tetraploid (40501–10 and 40501–14). (F) Flower of plant from second back-cross to carnation (41516–3). (G) Flower from seedling from F. (H) Progeny from intercrossed second back-cross plants.

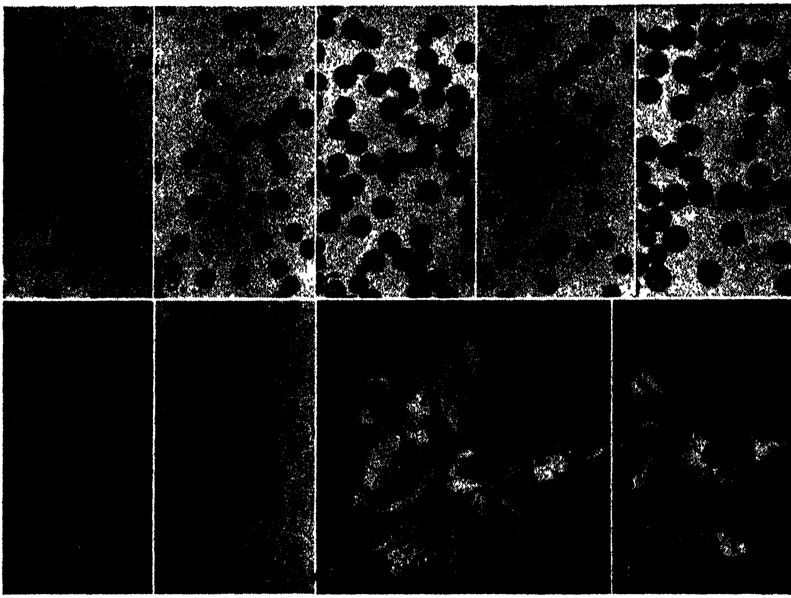


FIG. 2. (A) Pollen from *Dianthus Heddewigii*, 2n = 30. (B) Pollen from *D. chinensis*, 2n = 60. (C) Pollen from fertile F_1 hybrid 2n = 60. (D) Pollen from carnation, 2n = 30 (note two non-reduced grains). (E) Pollen from flower shown in Fig. 1, F. (F) Stomata from diploid carnation. (G) Stomata from tetraploid in Fig. 1, F. (H and I) Tetraploids showing papilliform outgrowths on lower side of petals.

whether *D. chinensis* and *D. caryophyllus* had this gene in common. The *thin* plant in question was true-breeding for pale salmon flower color. As *thin* is a recessive mutant from a normal carnation, it also bred true for this characteristic. Only 25 self seedlings had been grown from the *D chinensis* parent. There was segregation for several shades of colors and two plants had flowers that were nearly white. To see if a tetraploid hybrid might also occur in crosses where parents of commercial value had been used, more seed of all crosses where normal or superior types had been used was planted. From this planting over 500 additional hybrids were obtained but not a single tetraploid plant.

Meanwhile, a number of hybrids which had come from the first planting were self-pollinated and back crossed to both parents. The triploid plants gave no seed when self pollinated, no seed when pollinated by carnation pollen, and only a few shrivelled seeds when pollinated by *D. chinensis* pollen. On the other hand, the tetraploid produced an abundance of good and very large seeds (Fig. 1D) when selfed, fewer and poorer seed when *D. chinensis* pollen was used, and no seed from a number of pollinations with carnation.

The seeds obtained by self pollination of the tetraploid hybrid were planted immediately and produced over 200 seedlings, 100 of which were planted in the field. This F_2 progeny flowered in the Summer

of 1939. It was remarkably uniform in habit of growth. Not a single *thin* was recovered, but there was segregation for color. About one-fourth of the plants (21 out of 97) were of a peculiar pale-flowered type, peculiar in that the flowers were nearly white on opening but gradually deepened during the next two days until they reached almost but not quite the color of the F_1. Near-white segregates obtained from selfing the *chinensis* parent did not show the tendency for flower color to deepen. In addition to these pale-flowered plants, there were two plants with light pink flowers, and a few plants whose flowers were somewhat deeper in color and more of a crimson-purple than the F_1.

Two crimson-purple, two pale-flowered, the two light pink and two magenta flowered plants were self pollinated. The two light pink plants proved to be highly sterile and only one produced a few seeds. The two darker plants also produced few seeds but the other four plants seemed to be as fertile as the F_1.

In the following year (1940) another F_2 population of 200 plants was grown. This F_2 did not differ from that grown the previous year. No *thin* segregates occurred but there were two plants with light pink flowers, a number of dark-colored flowers, and 41 out of 192 were of the pale-flowered type. Eight plants died before flowering.

At the same time, 8 F_3 progenies totaling a little over 900 plants were grown. These were obtained from the F_2 plants that were self pollinated the previous year. The pale-flowered selections gave only pale-flowered plants, and the two dark colored selections gave prevailingly dark colors. Twelve plants from the F_2 light pink were all light pink. The two magenta-flowered plants repeated the segregation of the F_2 generation. A few F_3 plants were observed to be somewhat more like the parental types in habit of growth than the F_1 and F_2. They were self pollinated.

The F_4 population which totalled about 800 plants flowered during the Summer of 1941. Lines grown from F_3 plants resembling the parental types to some extent were quite distinct and one could readily see that some were closer to the *D. chinensis* parent, and others to the *D. caryophyllus* parent. One of the *caryophyllus*-like lines segregated for *thin* giving 19 *thin* out of a total of 93.

The segregates of the F_3 population which resembled the parental types produced fewer seeds than the others, and in the F_4 population (1941) it was found that very few seeds could be obtained from the plants that most resembled one of the parents. In 1942 the few plants produced by these seeds were so sterile that the selections had to be discontinued.

In 1939, in a line of otherwise typical carnations a pink flowered plant (39147–4) had been found that was exceptional in that it produced a relatively high number of large, presumable unreduced pollen grains (Fig. 2D). Pollen from this plant was used on two *D. chinensis* plants from the same line as the *chinensis* parent of the tetraploid F_1 hybrid. It was hoped that more tetraploid hybrids might thus be obtained, but from 55 seeds from two crosses only triploids were produced.

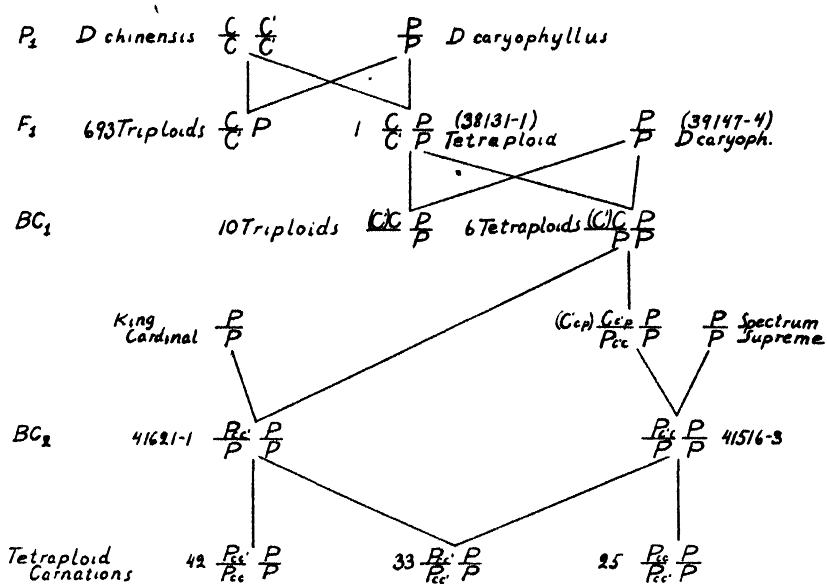
Pollen from the same plant was also used on several flowers of the tetraploid F_1 hybrid. One seed pod containing 19 seeds was eventually obtained. Seven of these seeds were as large as those obtained by selfing of the F_1 hybrid, whereas the other twelve seeds were much smaller. All were planted (1940) individually in pots and labelled as to size. The seven large seeds gave rise to the tetraploids one of which proved to be an accidental self seedling and was accordingly rejected. The others were back cross hybrids. The twelve smaller seeds gave rise to 10 triploid back cross hybrids. Two seeds failed to germinate. All sixteen hybrids, whether triploid or tetraploid, closely resembled the carnation (Fig. 1E). The 10 triploids had magenta-purple flowers and were sterile. Of the 6 tetraploid hybrids 5 had magenta-purple flowers and the sixth had deep pink flowers (40501–10). The purple tetraploids were highly fertile, but the deep pink was only moderately so. All the tetraploid back-cross hybrids were selfed and an F_2 generation was grown the following year. The deep pink hybrid bred true for pink flower color except that there was some variation in depth of color. The 5 purple flowered hybrids all segregated for deep pink approximately in 2:1 proportions (379 purple: 180 pink). There was considerable segregation for habit of growth. Many segregates were identical in appearance with the carnation but on the other hand in 559 plants no segregate approached the F_1 tetraploid parent.

In 1940, the deep pink tetraploid (40501–10) from the back-cross just discussed, and one of the purple tetraploid sister seedlings (40501–14) were pollinated with King Cardinal, a red-flowered commercial clone of the greenhouse carnation. Only one hybrid was obtained from the first named cross, a semi-double deep pink triploid. From the second cross (41516) three semi-double hybrids were obtained, one purple and one deep pink tetraploid (41516–3) and one deep pink triploid. In 1941, a seedling from the pink tetraploid (40501–10) was crossed to Spectrum Supreme, another red-flowered commercial clone. Only one hybrid was obtained, a semi-double deep pink tetraploid (41621–1).

In 1944, 25 self seedlings from (41516–3), 42 self seedlings from (41621–1) and 33 hybrids between these two tetraploids were flowered. The two parents and all of their progeny were similar to the common greenhouse carnation in general appearance (Fig. 1H) without any recognizable feature of *D. chinensis*. Their complete pedigree is shown in diagram I.

In general, these plants tend to have thicker and stiffer leaves and stems than the common diploid carnation. Some flowers were large for the cultural treatment they had received (Fig. 1F, G). These large flowers had unusually broad and thick petals. Some of the flowers had the papilliform outgrowths on the lower side of the petals (Fig. 2H, I) that are typical of so many recent autotetraploids (aster, snapdragon, annual larkspur and marigold). These features are usually indicative of tetraploidy, but are not positive diagnostic features. Two other features are more reliable for that purpose, namely, larger pollen size (Fig. 2A-E), and larger stomata and cell size of the epidermis (Fig. 2F, G). Chromosome counts have been made from root tips

DIAGRAM I



Explanation P= D. caryophyllus chromosome set, C,C' = D chinensis sets; Pc', Ccp, C'cp = interchanged chromosome sets.

on six plants only in the last generation. They were all tetraploid. Seed size, too, is approximately twice that of diploid carnations (Fig. 1D). Most of the plants that were selfed were reasonably fertile but more seeds were obtained when the sister seedlings were inter-crossed. In a few of these crosses occasional small seeds occurred. They have not yet been planted so it is not known whether they will give rise to diploids, as one might expect from the fact that their size is comparable to those of the diploid carnation.

A few of these tetraploid plants were pollinated by pollen from diploid carnations. Very few seeds were obtained, all of them being small and shrivelled. Fourteen crosses were made with *D. chinensis*. Four of these crosses produced a few poor seeds, none of which have as yet been germinated.

This year (1944), all seeds left over from crosses between *D. chinensis* and the carnation were re-examined for size. Every lot but one had uniform seed. This exceptional lot had one seed that was considerably larger than the rest (Fig. 1D). Interestingly enough, this lot was the same that had produced the tetraploid F_1 plant in

1938. This seed is now 7 years old and it is doubtful whether it is still viable, but if it should germinate, it will be interesting to see whether the large seed gives rise to another tetraploid.

Discussion

Hybrids between *D. chinensis* and *D. caryophyllus* have been reported by other investigators (1, 2, 3, 6). The chromosome numbers of these species and of horticultural forms derived from them have been determined by a number of investigators. All reports agree that *D. caryophyllus* and its derivatives are diploid (2n = 30). For *D. chinensis,* on the other hand, two different numbers have been reported. Ishii (7), Shibugawa (10), and Gentscheff (6) reported *D. chinensis* to be diploid (2n = 30), whereas Blackburn (5), Anderson and Gairdner (3), and Rohweder (9) reported it to be tetraploid (2n = 60). As shown in Table I, 2n = 60 was the number determined in this study on all accessions of *D. chinensis* except the varieties *Heddewigii* and *laciniatus*, both of which were diploid (2n = 30). The difference in number that has been reported for *D. chinensis* may in part be due to the inclusion of *Heddewigii* as a variety of *D. chinensis*, but it is more likely that diploid and tetraploid forms of *chinensis* occur. It is noteworthy that all tetraploid numbers have been listed under the name *D. sinensis* as if to indicate a difference, while all diploid forms have been reported as *D. chinensis*.

The *D. chinensis* used here is very similar to the type used by Amelung, as judged from his plate, and yet his type must have been diploid in order to give the results he reported. He obtained an F_1 which, when pollinated by carnation, gave an abundance of seed resulting in a back-cross population of over 200 plants which in turn set good seed, when pollinated by carnation again. The F_1 plants obtained here, with the exception of the one tetraploid, failed to give any seed when pollinated by carnation. Anderson and Gairdner too, report their F_1 plants from this cross to be highly sterile. Gentscheff does not state whether or not his hybrids were fertile, but they probably were, since both of his parental strains were diploid.

The F_1 sterility encountered here and by Anderson and Gairdner was probably due to the plants being triploid, a condition usually resulting in high sterility. If this assumption is correct, tetraploid hybrids obtained through non-reduction in the diploid parent should be less sterile. This assumption is supported by the fact that the one tetraploid F_1 plant obtained here was fully fertile.

Because of the difficulty in obtaining good cytological preparations in Dianthus by the usual smear techniques, no thorough study of meiosis in the fertile F_1 hybrid has yet been possible but the few satisfactory preparations obtained showed nothing but bivalents in the first metaphase. However, only one plate has been seen in which all the entities could be counted with certainty. It had 30 bivalents. Although these data are insufficient to permit definite conclusions regarding the meiotic behavior of this hybrid, the large amount of good seed obtained from it favors the assumption that the pairing at

meiosis is regular. Furthermore, from the relative uniformity of the F_2 progeny and particularly the fact that no *thin* individuals occurred in the F_2 and F_3 populations but did occur in the proportion of one *thin* to three normal in one of the F_4 lines, it must further be assumed that the pairing is prevailingly autosynaptic with only occasional allosynaptic pairing. The pale-flowered form that occurred in the F_2 and later generations in the proportion of one pale to three dark must have been due to segregation for near-white within the diploid *chinensis* complement but counteraction in the diploid *caryophyllus* complement caused a gradual coloring to take place in the course of a day or two. The few light pink individuals that occurred in the F_2 and F_3 generations as well as the few segregates in the F_3, which in appearance tended to approach the parental species, must have been due to allosynapsis.

Thus, it is evident that this hybrid satisfies all the requirements of an amphidiploid hybrid. The slight irregularities in pairing and consequent segregation that occur are counter acted by the increasing sterility of the segregates that tend to approach the appearance of the parental species. This, however, does not exclude the possibility that, if a large number of selections were made, a recombination product embracing largely characteristics of one species but with a few features of the other parent could be obtained.

The fact that this amphidiploid was the only fertile hybrid obtained between the carnation and *D. chinensis* in over 600 hybrid seedlings, and that hybridization between the carnation and *D. Heddewigii* proved so difficult indicate that the chances of transferring the attractive color patterns and perhaps other features from either *D. chinensis* or *D. Heddewigii* to the carnation are less likely than would be expected from the results reported by Amelung (2), Wichler (12) and Anderson and Gairdner (3).

The partial sterility of the amphidiploid hybrid with respect to both of its parents is somewhat surprising but even more so is the fact that the tetraploid derivatives, obtained by back-crossing this hybrid twice to the carnation, should be even more sterile when pollinated by either *D. chinensis* or carnation pollen and yet be fertile when selfed or interpollinated. More work will be necessary before an explanation for this behavior can be offered.

As soon as practicable an effort will be made to obtain autotetraploid carnations through colchicine treatment for comparison with these tetraploid hybrids, for although these hybrids look very much like what may be expected in the way of autotetraploids from colchicine or other similar treatment, there may nevertheless be differences, particularly with respect to meiosis. The details of meiosis remain to be investigated in the hybrids already obtained.

These tetraploids may have commercial possibilities. Four of the 100 plants grown this year were selected for propagation for cut flower trials. Whether they will prove better than the diploids remains to be seen. However, the fact that these hybrids have more chromosomes will make it possible to obtain many more combinations with respect to every characteristic feature of a commercial carnation, and,

despite the partial sterility in crosses with the diploid carnation, it will undoubtedly be possible to transfer to the tetraploids every useful color known in the diploids and also to produce triploids in every color, should they prove to be more useful.

Summary

In nearly 700 F_1 hybrids between tetraploid *D. chinensis*, 2n = 60, and diploid carnation, 2n = 30, one was tetraploid and fertile, all the others were triploid and sterile.

The fertile tetraploid hybrid behaves as a relatively stable amphidiploid.

Tetraploid back cross derivatives 3 generations removed from the F_1 look like autotetraploid carnations. They are self- and inter-fertile but set very few seeds when pollinated by either tetraploid *D. chinensis* or diploid carnations.

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Rooting of Cuttings From Plants Sprayed With Growth Regulating Substances

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DIFFERENT methods of application of growth regulating substances to promote rooting in cuttings such as soaking the bases in dilute solutions, dipping in highly concentrated solutions, in talc dust mixtures, and in lanolin pastes have been reported by various investigators. All of these methods involve treatment of the cutting after removal from the plant. No information is available regarding the practicability of applying growth substances in dilute sprays to the foliage at various intervals before the cuttings are taken, but Hildreth and Mitchell (3) have applied a spray of this type to cuttings in the propagating bed with success. Although the cost of this method may have seemed too great with the use of the indole and naphthalene compounds, the recently introduced halogenated phenoxy acids (5) are not only inexpensive, but remarkably effective at relatively low concentrations.

EXPERIMENTAL METHODS

The tests here reported were conducted with one of the most effective of these compounds, 2,4,5-trichlorophenoxyacetic acid and its sodium salt. In a few of the preliminary experiments, the free acid was dissolved in a small quantity of sulfonated castor oil and then brought to the desired concentration by diluting with water. Since this solvent alone appeared to promote rooting, all later experiments were conducted with the chemical dissolved in a small amount of ethyl alcohol (never more than one per cent of the final solution) and then diluted with water. The sodium salt of this compound is slowly soluble in water alone which was used in this case. One gram of sodium lauryl sulfate, a wetting agent, was added to each liter of solution.

In order to minimize variations due to temperature, all foliage spraying was done when the air temperature was above 70 degrees F, usually around noon or in the afternoon. Morning spraying was avoided on account of dew. The spray was applied with portable hand sprayers containing from one and one-half to four gallons of solution, and the foliage was sprayed thoroughly to a point where dripping was imminent in order to keep as much solution as possible on the leaves.

The cuttings used in these experiments were placed in a shaded greenhouse on open benches of washed river sand. Bottom heat was not provided until July 25 when the thermostatically-controlled electric soil heating cables beneath the sand in the benches were set at 70 degrees F for the remainder of the season. Humidification was maintained by means of centrifugal atomizers, as previously described by the writers (1, 2). The humidifiers were operated during the entire day in the early part of the summer, but cuttings made after July 25 were placed in a lean-to greenhouse with northern exposure only and the humidifier in this section was operated only for several hours during the middle of the day.

Lots of twenty cuttings each were placed in randomized blocks on the greenhouse benches. Five replications were used for each treatment, a total of 100 cuttings, with the sole exceptions of *Ilex vomitoria,* with which 60 cuttings were used, and *Ilex opaca,* with which 260 cuttings were used for each treatment. After the cuttings had rooted sufficiently for observation, they were lifted carefully from the sand and washed gently in water. The degree of rooting was classed in three grades according to arbitrarily selected standards, described as heavy, medium, and light. Experience has proved that if the differences cannot be determined from this grading, statistical studies on root weight, number, or length will usually fail to reveal significant differences due to treatments. However, the roots of many lots of cuttings were excised and weighed after drying.

Effect of Sprays on Rooting of Cuttings

These trials were only preliminary in nature and in some instances so few concentrations were used that the data are useful only as a guide to further experimentation. Since no information was available regarding the optimal dosage, some failures were to be expected from this source as too low concentration excites little response while too high tends to injure. The free acid was used only on *Buxus, Rhododendron,* and *Weigela,* and sodium trichlorophenoxyacetate was used in all other experiments. The plants, arranged alphabetically in Table I, show considerable variation in rooting response. With some species, showing little or no stimulation at a low concentration, highly significant responses were obtained at a higher concentration.

Little attempt has been made to correlate the concentration of the spray solution with dosages used in the standard methods of application. One trial was made with cuttings from unsprayed plants of *Buxus sempervirens Handsworthii* on August 8 treated by dipping the bases in a mixture of one part of indole butyric acid per 1000 parts of talc. These were compared with cuttings from plants sprayed with trichlorophenoxyacetic acid at a rate of 25 milligrams per liter of water. Oven-dry weights of the roots showed that the cuttings from sprayed plants produced 938 mg of dry matter and those dipped in the talc mixture produced 469 mg, but unsprayed and untreated cuttings produced only 215 mg. Spraying the foliage of *Pachysandra terminalis* with 25 mg/1 of trichlorophenoxyacetic acid failed to increase the per cent of rooting, but the application of a talc dust containing one part of indolebutyric acid per 1000 parts of talc to cuttings from unsprayed plants greatly increased both the per cent of rooted cuttings and the heaviness of rooting.

Individual branches on thirteen different clones of American holly (*Ilex opaca*) were sprayed on July 22 at concentrations ranging from 100 to 500 mg/1. Some injuries were observed later on the foliage of certain trees sprayed with concentrations above 200 mg/1, but other trees did not show these symptoms. Twenty cuttings were made of the best material from the sprayed portion of each tree and an equal number from the unsprayed part on several dates between August 8 and 30. When the cuttings were examined on Nov. 16, in ten of the

TABLE I—ROOTING OF CUTTINGS TAKEN FROM PLANTS SPRAYED WITH 2,4,5-TRICHLOROPHENOXYACETIC ACID OR ITS SODIUM SALT

Plants Sprayed		Cuttings		Per Cent Cuttings Rooted				Dry Wt Roots (Mgs)
Concentration Mg/l	Date	Taken	Examined	Total	Heavy	Medium	Light	
Buxus sempervirens Handsworthii (K. Koch) Dallimore								
None	—	Aug 14	Oct 11	40	4	5	31	215
25	Aug 5	Aug 14	Oct 11	63	13	26	24	938**
Buxus sempervirens var *suffruticosa* L.								
None	—	Aug 14	Oct 11	80	17	31	32	—
25	Aug 5	Aug 14	Oct 11	64	2	11	51	—
Cornus florida L.								
None	—	Aug 7	Sep 21	22	3	3	16	—
10	Jul 18	Aug 7	Sep 21	12	0	2	10	—
Ilex crenata var *convexa* Mak.								
None	—	Sep 26	Nov 8	40	1	6	33	108
50	Aug 19	Sep 26	Nov 8	56	4	15	37	193
100	Aug 19	Sep 26	Nov 8	77**	10	25	43	352**
Ilex Fargesii Franch.								
None	—	Aug 8	Nov 8	81	12	24	39	—
100	Jul 18	Aug 8	Nov 8	79	16	20	38	—
Ilex opaca Ait.								
None	—	Aug 15	Nov 16	51	18	16	17	—
100 500	Jul 22	Aug 15	Nov 16	35	10	8	17	—
Ilex vomitoria Ait.								
None	—	Aug 19	Jan 15	27	0	5	22	69
50	Jul 25	Aug 19	Jan 15	48	1	7	40	95**
100	Jul 25	Aug 19	Jan 15	48	15	16	17	230**
Ligustrum amurense Carr.								
None	—	Aug 14	Sep 16	84	45	24	15	1322
10	Jul 18	Aug 14	Sep 16	98	70	21	7	2846**
20	Jul 18	Aug 14	Sep 16	82	45	23	14	1756*
None	—	Sep 23	Oct 26	52	19	14	19	1041
10	Jul 18	Sep 23	Oct 26	50	15	15	20	1011
20	Jul 18	Sep 23	Oct 26	55	25	12	18	1307**
Ligustrum ibolium Coe								
None	—	Sep 27	Oct 13	100	29	56	15	922
50	Jul 25	Sep 27	Oct 13	95	8	50	37	749
None	—	Nov 9	Dec 14	87	15	25	47	653
100	Sep 25	Nov 9	Dec 14	91	38	25	28	1585**
Pachysandra terminalis Sieb. and Zucc.								
None	—	Aug 23	Oct 11	100	39	34	27	—
25	Aug 5	Aug 23	Oct 11	89	20	26	43	—
Rhododendron yedoense var. *poukhanense* (Levl.) Nakai								
None	—	Aug 11	Oct 11	46	12	12	22	—
25	Aug 5	Aug 11	Oct 11	68*	8	21	39	—
Symplocos paniculata (Thunb.) Miq.								
None	—	Jun 26	Sep 21	21	3	2	16	—
20	May 29	Jun 26	Sep 21	18	0	5	13	—
Weigela floribunda (Sieb. and Zucc.) C. A. Mey.								
None	—	Jun 5	Jun 24	67	0	12	55	—
50	May 22	Jun 5	Jun 24	39	11	20	8	—

*Indicates effect of treatment significantly different from no treatment at the 5 per cent level of probability.
**Indicates effect of treatment significantly different from no treatment at the 1 per cent level of probability.

thirteen clones more cuttings from the unsprayed branches had rooted than from the sprayed and likewise the rooting was heavier. The advantage of the spraying was very slight with the three remaining clones. The total per cent rooted for each class is shown in Table I.

The behavior of softwood cuttings of sprayed highbush blueberries varied remarkably with the concentration. In some instances, even when no external effects whatever were visible on the stock plants, cuttings died immediately after they were placed in the rooting medium. All cuttings from plants sprayed with a concentration of sodium trichlorophenoxyacetate at 125 milligrams or more per liter behaved in this manner, but those from plants receiving a spray containing 62.5 mg per liter rooted excellently.

Possibly rooting may be promoted in hardwood cuttings by spraying the foliage in the summer preceding the dormant season in which the cuttings are made. A preliminary experiment in the summer of 1943 which consisted in spraying the foliage of black locust (*Robinia pseudo-acacia* L.) resulted in a definite improvement in both the per cent and the heaviness of rooting of hardwood cuttings taken from sprayed branches in the early spring of 1944. Hitchcock and Zimmerman (4) have shown that the influence of a summer spray of growth substance on the foliage may be carried over and produce a characteristic effect in delaying opening of flower buds in the following season.

Effects of Sprays on the Stock Plants

Noticeable effects were observed on the foliage of the sprayed plants in many instances. Epinasty of the leaves and terminal portions of growing shoots was common. Some plants showed discoloration of the foliage, suggesting disintegration of the chlorophyll, particularly with the higher concentrations of the spray solution. Sprays of indole and naphthalene compounds applied to highbush blueberry plants in May and sprays of sodium trichlorophenoxyacetate in June caused shoot elongation to cease for the entire season. The injury caused by Japanese beetles to the foliage of sprayed blueberries was much more severe than to the foliage of unsprayed plants or parts of plants purposely left unsprayed for control purposes. Apparently, changes in the leaves caused by the spraying rendered the foliage more attractive to the beetles.

Another notable effect was observed on bushes of *Ligustrum compactum* Hook. f. & Thoms. sprayed on May 22 with sodium trichlorophenoxyacetate at 50 mg/1. Although the concentration of the spray solution may have been above the optimum, cuttings from sprayed plants rooted heavily and quickly, but those from unsprayed plants rooted only sparsely when held all summer in the propagating bench. All bud growth on the sprayed plants was completely inhibited until the latter part of the summer when the terminal shoots made a vigorous growth, although the laterals remained suppressed as before. The leaves on the vigorous terminal growths were much larger than normal and had an unusually deep green color. This foliage persisted longer in the fall than that of the unsprayed plants.

Discussion

These experiments must be considered as preliminary in nature, but they indicate that if plants are sprayed with 2,4,5-trichlorophenoxyacetic acid or its sodium salt in a suitable concentration, the cuttings taken from such plants after a certain interval show essentially the same rooting responses as do cuttings treated with growth substances according to one of the generally accepted methods. These experiments are not sufficiently extensive to indicate the most desirable time interval between the application of the spray and the making of the cuttings. A suggestion that the effect gradually diminishes with time is seen in the two experiments with *Ligustrum amurense*. The plants were sprayed on July 18 and with cuttings taken on August 14. The best rooting was obtained with a spray of 10 mg/l and the concentration of 20 mg/l was definitely too strong. However, with cuttings taken from the same plants on September 23, the higher concentration gave the better response and no improvement in rooting occurred with the lower.

These experiments indicate the necessity of adjusting the concentration of the spray to the different species of plants in order to obtain the best results, a problem which is present irrespective of the manner of applying growth regulating substances. Whether or not the external effects sometimes observed on sprayed stock plants may persist and cause abnormalities in the following season is undetermined. Further investigations are needed on the concentrations, most suitable stages of growth for application, and the time interval between spraying and taking cuttings.

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Susceptibility of Yoshino, Akebono and Beni-Higan Flowering Cherry Trees to Spray Oil Injury[1]

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PROBABLY no ornamental planting of trees has received so much public favor in the United States as have the Yoshino and Akebono oriental flowering cherry trees (*Prunus yedoensis* Matsum.) which surround the Tidal Basin in Washington. In normal times, when the trees come into bloom in the spring, the city overflows with visitors who come from all over the country to share with the people of Washington their delightful beauty. Any trouble affecting these trees, therefore, may be considered as having more than local importance.

The writer first noted an important amount of fresh twig and branch die-back in these trees on May 7, 1940. Available information indicates that the same condition, and to about a similar extent, had previously developed in this planting on the Yoshino variety in 1936 and 1939 after the trees had flowered. Although no systematic surveys were made at that time, it is reported that several varieties of *Prunus serrulata* Lindl. were not affected.

The cause of the die-back had been variously attributed to flood injury, adverse site and winter injury. The possibility of injury by spray materials was considered, but little or no direct evidence in this regard was found. With the advent of the die-back noted in 1940, it seemed advisable to pursue the investigation further.

SURVEY OF CHERRY TREES FOR DIE-BACK, SYMPTOMS, AND ASSOCIATION OF CAUSE TO SPRAY OIL INJURY

Within one week of the time the above injury was first observed a survey of nearly all flowering cherry trees in the parks, on both the White House and U. S. Capitol grounds, for the injury was completed. Data on the trees investigated included identification, approximate age, vitality, and any spray treatments that had been applied in the previous dormant season. These facts are summarized in Table I.

The varieties examined in the survey were as follows: Yoshino, *Prunus yedoensis;* Akebono, *P. yedoensis;* Kwanzan, *P. serrulata;* Tankoshinju, *P. serrulata,* Shiro-fugen, *P. serrulata;* Gyoiko, *P. serrulata;* Sargent cherry, *P. sargenti* Rehd.; and Beni-higan, *P. subhirtella* Miq. The Yoshino is considered a hybrid between *P. serrulata* and *P. subhirtella*, and Akebono is a seedling selection of the Yoshino made by W. B. Clarke of San Jose, California, while the other kinds are recognized as of individual species.

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[1]The writer is very grateful to Paul Russell for help in identifying the flowering cherry trees, to Dr. J. W. Roberts, G. F. Gravatt and E. L. Green for conferences on the injury, all of the Bureau of Plant Industry, Soils, and Agricultural Engineering, U. S. D. A., and to the Divisions of Fruit Insect Investigations and Forest Insect Investigations of the Bureau of Entomology and Plant Quarantine, U. S. D. A. for criticism of the paper.

TABLE I—SURVEY OF FLOWERING CHERRY TREES IN WASHINGTON, D. C. FOR TWIG DIE-BACK IN 1940, AND POSSIBLE RELATIONSHIP OF SPRAY OIL TO THE INJURY

Locality	Variety	Date Sprayed (Mo/Days)	Approx. Age of Trees (Years)	Average Vitality	Total Trees	Percentages of Trees Showing Different Amounts of Twig Mortality: 1–10 (Per Cent)	11–20 (Per Cent)	21–40 (Per Cent)	41–60 (Per Cent)	Total Trees Injured (Per Cent)
				Miscible Oil 1–19						
Tidal Basin	Yoshino	3/9–20	8–12	High	120	39.2	9.2	20.0	5.8	74.2
Tidal Basin	Yoshino	3/9–20	24–34	Fair-good	424	51.4	32.0	12.9	0.2	96.5
E. Potomac Park	Yoshino	3/9–20	24–34	Fair-good	42	19.0	52.4	28.6	0.0	100.0
E. Potomac Park	Akebono	3/9–20	8	High	55	20.0	7.3	2.0	2.0	31.3
E. Potomac Park	Kwanzan	3/9–20	24–34	Fair-good	94	0.0	0.0	0.0	0.0	0.0
E. Potomac Park	Kwanzan	3/9–20	8	Good	55	0.0	0.0	0.0	0.0	0.0
E. Potomac Park	Tankoshinju	3/9–20	24	Fair	24	0.0	0.0	0.0	0.0	0.0
E. Potomac Park	Shirofugen	3/9–20	12	Good	21	0.0	0.0	0.0	0.0	0.0
E. Potomac Park	Benihigan*	3/9–20	8	Fair-good	About 350	—	—	—	—	—
W. Potomac Park	Sargent	3/9–20	12	Good	4	0.0	0.0	0.0	0.0	0.0
White Hs Grounds	Gyoiko	3/9–20	24–34	Good	8	0.0	0.0	0.0	0.0	0.0
				Lime-Sulphur, Winter Dilution						
Capitol Grounds	Yoshino	—	24–34	Good	5	0.0	0.0	0.0	0.0	0.0
				No Spray Treatment						
E. Potomac Park Nursery	Yoshino	—	3	High	119	0.0	0.0	0.0	0.0	0.0

*Estimated 40 per cent of the trees of this variety had 1–40 per cent of their twigs killed.

Die-back was found only among Yoshino, Akebono, and Benihigan trees. It seems noteworthy that all the varieties injured were related to *P. subhirtella*, but apparently of greater significance was the fact that all the injured trees had been sprayed with a miscible oil diluted 1–19, as trees frequently have been reported injured by dormant spray oils. Mason (1) states the greatest caution should be employed in applying spray oils to stone fruits (which includes cherry trees), even in the dormant season. Britton (2) describes the stone fruits, peach and Japanese plum, as especially susceptible to oil injury.

The die-back was severest in the last season's twig growth, becoming progressively less so in older wood and rarely extending beyond 3-year-old branches, and then mostly on young vigorous trees. Although the trees had completed flowering about three weeks before, an abundance of brown withered petals was still found clinging to the injured growth, showing that acute injury apparently had set in suddenly before normal petal fall, thereby arresting their natural abscission. Few leaves had unfolded on the injured twigs and they usually appeared stunted, deformed and more or less completely blackened. The injured twigs almost invariably failed to recover, and no new occurrence of the trouble developed after May 7 for that season. Typical injury, as observed on Yoshino trees around the Tidal Basin, is illustrated in Fig. 1.

FIG. 1. Twig and branch die-back on large Yoshino flowering cherry trees, connected to spray oil injury. Tidal Basin, Washington, D. C. Photographed May 13, 1940, by Abbie Rowe.

In the Tidal Basin planting, where oil had been applied on 120 and 424 Yoshinos, 8–12, and 24–34 years old, respectively, 74.2 per cent of the younger group and 96.5 per cent of the older group were injured. In the same planting 31.5 per cent of 55 Akebonos, about 8 years old, was injured. In East Potomac Park, where 42 Yoshinos, about 34 years old, and approximately 350 Beni-higans about 8 years old, were sprayed with oil, 100 per cent of the former and about 40 per cent of the latter were injured. While fewer of the younger than older Yoshinos were affected, the severest injured individual cases, nevertheless, occurred among the younger trees, where branches were killed back to the main trunk; one tree was injured so severely that it died early in the summer, after producing a thin crop of small leaves. No injury, however, was found on five Yoshinos, about 25 years old, sprayed with lime-sulphur on the U. S. Capitol grounds, or 119 3-year-old Yoshinos in the East Potomac Park nursery which had not been sprayed, indicating that oil might be responsible for the die-back. Although Kwanzan, Tanko-shinju, Shiro-fugen, Gyoiko and Sargent cherry also were sprayed with oil, no injury developed.

A review of spray treatments received by the cherry trees in the past, showed that from approximately 1914 to 1930 lime-sulphur had been used, but since then a single brand of miscible oil at 1–19 had been applied exclusively. While it had been the usual practice to spray the trees in the dormant season every year for San Jose scale, *Aspidiotus perniciosus* Comst., and West Indian peach scale, *Aulacaspis pentagona* Targ., occasionally a year was skipped. Reliable informa-

tion on actual years the trees had been sprayed with oil, however, is available back to 1936 and shows the use of miscible oil regularly, except in 1938. Oil having been associated with the injury in 1940, it seemed reasonable to attribute a like injury, observed in 1936 and 1939, to the same cause. Absence of injury in 1938 was accepted tentatively as circumstantial evidence that oil was the responsible agent as the trees had not been sprayed that year but, on the contrary, no injury developed in 1937 in spite of the fact that the trees had been sprayed with oil.

The lack of injury in the *Prunus serrulata* varieties and Sargent cherry sprayed with the miscible oil indicated nothing particularly wrong with the spray material. It seemed, therefore, that the Yoshino, Akebono and Beni-higan varieties were subject to oil injury only under certain conditions. Various workers, including Felt and Bromley (3) and Wakeland (4) have claimed that freezing soon after application of oil is harmful to trees. Newcomer and Yothers (5), however, found such a condition harmless to apple trees sprayed with oil in February, and Overley and Spuler (6) reported oil emulsions sprayed on apple trees January 19 during freezing weather caused little or no injury. Examination of the United States Weather Bureau reports for Washington showed no freezing weather during the days or the following nights that the trees were sprayed, except one night when a minimum of 32 degrees F was reached, a temperature hardly low enough to be significant. It was apparent that more conclusive evidence on the susceptibility of Yoshino, Akebono, and Beni-higan cherry trees to oil injury was desirable and was obtained for Yoshino in spray tests, conducted in 1941, 42 and 43.

1941 Spray Tests

The 1941 spray tests included the same brand of miscible oil which had been sprayed on the trees before, an oil emulsion and lime-sulphur. Both spray oils are of the stable type. Through the courtesy of R. C. Roark of the U. S. Dept. of Agriculture, analyses of the oils were obtained for oil content, unsulfonatable residue, and viscosity (Table II).

TABLE II—Analyses of Spray Oils by the U. S. Department of Agriculture

Oil Type	Oil (Per Cent)	Unsulfonatable Residue (Per Cent)	Viscosity, Saybolt Units at 100 Degrees F
Miscible (applied 1941, 1942, 1943)	99	64	121
Oil emulsion (applied 1941, 1942)	91	64	105

The analyses of both oils compared favorably with standards set up by the Western Cooperative Oil Spray Project[2], which advocated for dormant spray oils an unsulfonatable residue content of 50–70 per cent, and a viscosity of 100–120 Saybolt units at 100 degrees F.

[2]Ore. Agr. Exp. Sta. Bul. 321. 1933.

The miscible oil was diluted 1–19 to repeat the formula employed in the past and resulted in a spray having an oil content of practically 5.0 per cent. This dilution had been very satisfactory from the standpoint of control of the scales mentioned, and is commonly employed for controlling scale insects on ornamentals. The oil emulsion was diluted 1–24, giving an oil content of 3.6 per cent. Snapp (7) recommends that oil emulsions should contain 3.0 per cent actual oil for control of the above scale species on peach trees, but that peach can tolerate, without danger other than the possibility of a slight delay of the blooming period, a 6 per cent oil emulsion. The lime-sulphur, a commercially prepared product, had a specific gravity of 33 degrees Baumé and was diluted 1–9, a strength understood to have been applied to the trees in past years. Kotinsky (8) recommends this material diluted 1–8 and 1–9.5 for scale insects on ornamentals.

The spray tests were conducted on 4 and 25–35-year-old Yoshino trees. The 4-year-old trees were in the East Potomac Park nursery, and in extremely vigorous condition, whereas the 25-to-35-year-old trees in the same park and around the Tidal Basin were, respectively, in generally good-to-fair vigor. Seven to 29 trees made up each test. These were sprayed during March 27–29, 1941, under conditions of moderate temperature.

While the trees were coming into bloom, they were examined daily for evidence of injury. The old trees came into full bloom on April 13 and the young trees a day later. Old trees, sprayed with both oil sprays, developed floral wilt suddenly a day after coming into full bloom. The wilt continued developing until the following day. Further symptoms involved general dying of leaf buds and immature leaves, but on twigs slightly injured the leaf buds were sometimes delayed for several days to several weeks from coming out. While most of the twigs were observed dying back from the tip, the tips of a few of the affected twigs showed no evidence of injury and were foliating. Later, however, many of them died because of the injury below. The sapwood of badly injured twigs occasionally was observed taking on a water-soaked appearance, which later turned brown, but frequently the sapwood remained white. The cortex in badly injured twigs frequently was browning throughout, while in slightly injured twigs it was developing brown streaks next to the cambium or appeared normal. Young trees presented similar symptoms; the wilt symptoms, however, were several days later in developing.

Old Yoshino trees sprayed with lime-sulphur bore outward symptoms somewhat similar to those following the use of oil, except the wilt symptoms came on more gradually, affecting only weak growth and then only slightly, whereas oil injured both strong and weak growth, sometimes severely. Results of these spray tests are summarized in Table III.

Old trees, sprayed with miscible oil and oil emulsion respectively had 1–60 per cent and 1–40 per cent of their twigs injured, while similar trees sprayed with lime-sulphur had only 1–5 per cent of their twigs affected. Lime-sulphur affected only weak growth, while the oil sprays affected weak and strong growth. Young trees were much

TABLE III—INJURY OF YOSHINO CHERRY TREES FROM OIL AND LIME-SULPHUR SPRAYS IN 1941

Locality	Date Sprayed (Mo/Day)	Approx Age of Trees (Years)	Ave Vitality	Period in Full Bloom (Mo/Days)	Commencement of Floral Wilt (Mo/Day)	Total Number of Trees	Number of Trees, Showing Amount of Twigs Injured					
							None	1–5 (Per Cent)	6–10 (Per Cent)	11–20 (Per Cent)	21–40 (Per Cent)	41–60 (Per Cent)
				Miscible Oil 1–19								
Tidal Basin	3/27	25–35	Fair	4/13–15	4/14	29	0	9	8	9	3	0
E. Pot. Pk. Orchard	3/29	25–35	Good	4/13–15	4/14	7	0	1	1	2	2	1
E. Pot. Pk. Nursery	3/27	4	High	4/14–17	4/17	15	8	6	1	0	0	0
				Oil Emulsion 1–24								
Tidal Basin	3/27	25–35	Fair	4/13–15	4/14	15	0	3	9	1	2	0
E. Pot. Pk. Orchard	3/27	25–35	Good	4/13–15	4/14	6	0	6	0	0	0	0
E. Pot. Pk. Nursery	3/27	4	High	4/14–17	4/17	17	15	2	0	0	0	0
				Lime-Sulphur 1–9								
Tidal Basin	3/28	25–35	Fair	4/13–15	4/14	22	11	11	0	0	0	0
E. Pot. Pk. Nursery	3/28	4	High	4/13–15	——	20	20	0	0	0	0	0
				Check								
Tidal Basin	——	9–35	Fair-to-good	4/13/15	——	544	544	0	0	0	0	0
E. Pot. Pk. Orchard	——	25–36	Good	4/14–15	——	17	17	0	0	0	0	0
E. Pot. Pk. Nursery	——	4	High	4/14–17	——	36	36	0	0	0	0	0

less affected by the oil sprays and not at all by lime-sulphur. Seven of 15 young trees, sprayed with miscible oil, had 1–10 per cent of their twigs injured, while only two of seventeen similar trees, sprayed with oil emulsion, were injured and then only to the extent of 1–5 per cent of their twigs. Miscible oil was more injurious than oil emulsion, apparently because the spray bore a higher oil content. Significant numbers of unsprayed trees around the Tidal Basin in East Potomac Park and in the nursery of East Potomac Park were not injured. These results indicated conclusively that the injury described, was caused by the spray materials, and confirmed the writer's diagnosis of the die-back, observed on Yoshino, Akebono, and Beni-higan trees in the parks in 1940, as oil-injury.

When the Yoshino trees were sprayed (March 27–29, 1941) it was noted that the flower buds already had started to swell and were about one-third larger than in the dormant condition, thus proving that the trees were in an active state of development. At the same time, flower buds of the *Prunus serrulata* and *P. sargenti* trees were still relatively tight. This indicated the difference between injury of the Yoshino in the past by spray oil, and that resistance of the varieties of *P. serrulata* and the species *P. sargenti* to this material probably was somehow related to the greater activity of the former at the time of spraying.

Overley and Spuler (6) found apple trees quite resistant to oil injury, when sprayed before bud development had started, but susceptible to injury from oil after sufficient swelling had occurred to cause separation of the bud scales.

1942 Spray Tests

To test whether Yoshino was more susceptible to oil injury after the flower buds had begun to swell than prior to that time, old and young trees were sprayed, February 6, and March 11 and 25, when the flower buds were respectively tight, quarter and half swollen, with the same oils tested in 1941. The miscible oil was diluted 1–19 as in 1941, but the oil emulsion was diluted to 1–29 rather than 1–24 as in the previous year. Lime-sulphur, 33 degrees Baumé, diluted 1–9, was also included in the same series with the oil sprays, except that young trees were not sprayed in the second part. Five to 14 old trees around the Tidal Basin and 7–10 young trees in the East Potomac Park nursery were selected for each spray test. No freezing weather occurred during the days the sprays were applied, or the nights following. Data on twig injury from the above sprays are summarized in Table IV.

Significant injury again resulted from the oil sprays, and in negligible degree from lime-sulphur, on weak twig growth of old trees. The time the oil sprays were applied was found generally important in the amount and degree of injury obtained, more injury coming from the sprays applied in March when the flower buds were swelling than in February when they appeared dormant—a condition particularly more evident among the young than the old trees.

In the old trees, miscible oil injured 1 to 20 per cent of the twigs of 8 of 13 trees sprayed February 6, and the same range of injury was obtained for all of 11 and 6 trees sprayed March 11 and 25.

The same succession of sprays repeated on young trees, however, caused no injury to 10 trees sprayed February 6, but injured up to 10 per cent of the twigs of 8 of 10 trees sprayed March 11 and the same for all of 9 trees sprayed March 25. Oil emulsion injured up to 10 per cent of the twigs in 5 of 10 old trees sprayed February 6, and a like amount of injury in 2 of 6 similar trees sprayed March 11, but all of 5 old trees sprayed March 25 had 1 to 20 per cent of their twigs injured. In contrast with the old trees, 10 and 7 young trees sprayed with oil emulsion February 6 and March 11 remained free of injury, but 2 of 8 young trees sprayed with this material March 25 had 1 to 5 per cent of their twigs injured. Comparable old and young trees, sprayed with lime-sulphur in the above series remained free of injury, with the exception of 1 to 5 per cent of the twigs in 2 of 14 old trees sprayed February 6, but the injury only affected weak growth. Eight old and 25 young trees, not sprayed, were not injured, thus indicating that the injury observed was caused by the sprays.

1943 Spray Test

In 1943, only the miscible oil was tested and was applied February 22, 1943, at 1–19 on 14 of the old Yoshino trees around the Tidal

TABLE IV—INJURY OF YOSHINO CHERRY TREES FROM OIL AND LIME-SULPHUR SPRAYS, APPLIED AT DIFFERENT STAGES OF FLOWER-BUD DEVELOPMENT IN 1942

Locality	Date Sprayed	Flower-Bud Stage	Approx. Age of Trees (Years)	Ave. Vitality	Period in Full Bloom (Mo/Days)	Beginning of Floral Wilt (Mo/Day)	Total Number of Trees	Number of Trees, Showing Per Cent of Twigs Injured: None	1–5 (Per Cent)	6–10 (Per Cent)	11–20 (Per Cent)	21–40 (Per Cent)	41–60 (Per Cent)
					Miscible Oil 1–19								
Tidal Basin	2-6-42	Tight	26-36	Fair	4/7-10	4/6	13	5	1	3	4	0	0
E. Pot. Pk. Nursery	2-6-42	Tight	5	High	4/8-11	4/7	10	10	0	0	0	0	0
Tidal Basin	3-11-42	25 per cent swollen	26-36	Fair	4/7-10	4/6	11	0	3	6	2	0	0
E. Pot. Pk. Nursery	3-11-42	25 per cent swollen	5	High	4/8-11	4/7	10	2	3	5	0	0	0
Tidal Basin	3-25-42	50 per cent swollen	26-36	Fair	4/7-10	4/6	6	0	1	1	4	0	0
E. Pot. Pk. Nursery	3-25-42	50 per cent swollen	5	High	4/8-11	4/7	9	0	2	7	0	0	0
					Oil Emulsion 1–29								
Tidal Basin	2-6-42	Tight	26-36	Fair	4/7-10	4/6	10	5	4	1	0	0	0
E. Pot. Pk. Nursery	2-6-42	Tight	5	High	4/8-11	4/7	10	10	0	0	0	0	0
Tidal Basin	3-11-42	25 per cent swollen	26-36	Fair	4/7-11	4/6	6	4	1	1	0	0	0
E. Pot. Pk. Nursery	3-11-42	25 per cent swollen	5	High	4/8-11	4/7	7	0	0	0	0	0	0
Tidal Basin	3-25-42	50 per cent swollen	26-36	Fair	4/7-10	4/6	5	0	0	1	4	0	0
E. Pot. Pk. Nursery	3-25-42	50 per cent swollen	5	High	4/8-11	4/7	8	6	2	0	0	0	0
					Lime-Sulphur 1–9								
Tidal Basin	2-6-42	Tight	26-36	Fair	4/7-10	4/7	14	12	2	0	0	0	0
E. Pot. Pk. Nursery	2-6-42	Tight	5	High	4/8-11	—	10	10	0	0	0	0	0
Tidal Basin	3-11-42	25 per cent swollen	26-36	Fair	4/7-10	—	10	10	0	0	0	0	0
Tidal Basin	3-25-42	50 per cent swollen	26-36	Fair	4/7-10	—	5	5	0	0	0	0	0
E. Pot. Pk. Nursery	3-25-42	50 per cent swollen	5	High	4/8-11	—	10	10	0	0	0	0	0
					Check								
Tidal Basin	—	—	26-36	Fair	4/7-10	—	8	8	0	0	0	0	0
E. Pot. Pk. Nursery	—	—	5	High	4/8-11	—	25	25	0	0	0	0	0

Basin. No freezing weather was encountered during the spraying or until four days later. The flower buds showed very slight evidence of swelling when the spray was applied. Twenty-one similar trees at the same location were not sprayed.

The trees came into full-bloom on April 4, 1943, but no more than a trace of injury developed, and that in but 4 of the 14 trees sprayed. The non-sprayed trees remained healthy. The amount of injury observed from the miscible oil was so slight that it could easily have been overlooked, and apparently compared very favorably with that in 1937 when no injury was reported on Yoshino trees sprayed with miscible oil by National Park Service officials.

Discussion and Conclusions

It is apparent from the results presented that the Yoshino variety may vary considerably from time to time in its tolerance of spray oil. The conditions that bring about these different results are not entirely understood. None of the trouble could be explained by sudden cold weather following the sprayings. In the 1942 spray tests, young trees proved completely resistant to oil injury when the sprays were applied before the flower buds had started to swell. After the buds of young trees were quarter swollen, injury was caused only by the miscible oil, but after the buds were half swollen, injury was obtained by both miscible and oil emulsion. These results indicated that the amount of activity, manifested by flower-bud swelling, possibly was sufficient to make the trees susceptible to oil injury. Old trees, however, in the same series with the young trees in 1942 proved susceptible to injury from both spray oils in each stage sprayed, but more injury generally developed after the flower buds commenced to swell. It is possible that the old trees, in the earliest application of the oil, proved more susceptible to oil injury than did the young ones because of their lower vitality. Britton (2) claims weak trees are more susceptible to oil injury than those in high vigor. The spray test in 1943, however, showed old Yoshino trees may be sprayed with the miscible oil in the dormant season without incurring more than a negligible amount of injury. Possibly the trees sprayed in 1943, although sprayed February 22, actually were in a deeper state of dormancy than those sprayed the year before on February 6. But not all the trees sprayed in a post-dormant condition in 1941 and 1942 were injured, and of those injured, by no means were all their twigs affected. These results indicated that the degree of activity as manifested by bud swelling is not the only factor on which such injury by spray oil impinges.

Another factor, which possibly has a closer connection with the onset of oil injury in trees more or less dormant, is the oxidizing power of the sap. Tucker (9) has demonstrated that the hydrocarbons of spray oils do not become toxic to apricot foliage in a chemical sense under natural conditions until oxidized to an approximate minimum of 0.5 per cent of asphaltogenic acids. He found oxygen and sunlight of paramount importance in this reaction—the latter acting as an activator. Judging by the killing of twigs and branches by spray oil in the Yoshino, Akebono and Beni-higan cherry trees, it may be assumed that these materials or products derived from them penetrated vital tissue and killed them, but as the hydrocarbons of spray oils are harmless until oxidized, injury hardly could have developed without that reaction having first occurred. Although Tucker found that leaves were injured by oil only when exposed to artificial or sun light in air, this does not necessarily mean that light is always essential as it simply serves as an activating agent. In injury of twigs and branches of the cherry trees from oil, it seems questionable that sunlight could sufficiently penetrate the cortex and buds to exert any important chemical reaction or effect the oil significantly before penetration. Perhaps oxidation of the oil is also influenced by the con-

stituents of the sap. Thomas (10) mentions that many substances, stable when exposed to molecular oxygen, are readily oxidized aerobically in living cells. Time to time variation in the oxidizing power of the sap might very readily account for variable results in the amount of oil injury obtained under apparently identical conditions.

Summary

Investigation is here reported of a serious twig and branch die-back condition of the Yoshino, Akebono, and Beni-higan flowering cherry trees in the National Capital Parks, Washington, D. C.

Evidence is presented from a survey of the condition in 1940 that it resulted from oil injury caused by a miscible spray oil, diluted 1–19. The following cherry varieties although similarly sprayed, however, were not affected: Kwanzan, Shiro-fugen, Tanko-shinju, Gyoiko, and Sargent cherry.

Spray tests in 1941 with miscible oil 1–19, oil emulsion 1–24 and lime-sulphur 1–9 on old and young Yoshino trees established that the injury observed in 1940 was definitely oil injury. The symptoms are described.

Spray tests in 1942 with miscible oil 1–19, oil emulsion 1–29, and lime-sulphur 1–9 on old and young Yoshino trees showed old trees may be injured almost as readily by oil when the buds are tight as when quarter to half swollen but not young trees, which proved susceptible to the miscible oil only after the buds were quarter to half swollen, and to oil emulsion only after the buds were half swollen. Lime-sulphur proved practically non-injurious, causing negligible injury only to weakened growth in two of fourteen trees sprayed when the buds were tight.

In 1943, miscible oil tested on old Yoshinos when the buds were showing very slight evidence of swelling, resulted in negligible injury.

Wide differences in injury of Yoshino by spray oil under apparently identical conditions are suggested as possibly attributable to variations in the power of the sap to oxidize innocuous hydrocarbons of spray oils to harmful amounts of asphaltogenic acids.

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Growth and General Performance of Plant Materials Used as Hedges

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MOST of the 115 hedges in the Hedge Demonstration Plot of the Arnold Arboretum were planted either in the fall of 1936 or in the spring of 1937. The majority have grown well since and it seems to be advisable to make a report on their growth performance to date. They have received a minimum amount of care. The grass walks between them have been mowed regularly, and all plantings have received at least one application of well-rotted manure. Most of the deciduous hedges were cut to within six inches of the ground when they were planted, this being done in order to insure bushy growth. Of course, the evergreen hedges were not treated this way, their growth now being largely proportional to the size of the plants when they were originally received.

Pruning or clipping has been held to a minimum, usually done on deciduous as well as evergreen hedges during the latter part of June or the early part of July at a time when the current year's growth was about complete. One pruning or clipping at this time was usually sufficient each year, although a few of the plants needed an additional light clipping in the fall. This additional clipping was the exception rather than the rule. All hedges have been clipped in the same form, i. e., narrow and slightly rounded at the top and wider at the base, since this slightly triangular shape is conducive to best hedge growth (1).

Seven plants were placed in each of the larger-growing hedges and ten plants were placed in most of the smaller growing, the length of each hedge after planting being approximately 25 feet. Full details concerning the plot as it was originally planted, together with a plan, will be found in the Bulletin of Popular Information of the Arnold Arboretum (2).

A large number of these hedges have proved to be very satisfactory up to this time. The advantages of using one kind of plant material in preference to another depends on the purposes for which the hedge is intended. Such important items as the size of the leaves, presence or absence of thorns, color of flowers and fruit, and texture, all enter into the selection of plant material for hedges, but these are not considered in this paper. This report is based primarily on growth made to date and it is of value merely to note the large number of species that have grown into good hedges since this demonstration plot was planted. Good hedges are bushy at the base; and many of these plants have grown together in the hedge rows to make continuous masses of plant materials and give every indication of responding well to clipping in the future.

Some of the hedges have not proved to be satisfactory within this trial period, and the species are listed together with the reasons why they have proved to be unsuitable. Some, especially those that have

LIST I—Plants Which Have Proved to be Satisfactory as Hedges

(Note: These are all very dense, well branched completely to the ground and grown together to form continuous hedges. Naturally their *texture* varies with size of leaf. Interest varies with flower, fruit and autumn color. But as eight-year old hedges, they are all satisfactory at their respective heights and widths. The figures in the second column are the original heights of the plants as they came from the nursery. Those marked (*) were cut to within 6 inches of the ground immediately after they were planted in order to force them to branch well from the base.)

Name	Year Planted	Height of Plants Prior to Planting	Height of Clipped Hedge Dec 1, 1944	Width of Clipped Hedge Dec 1, 1944
Acer campestre	1936	*2–4′	4′	4′ 6″
Acer Ginnala	1936	*5–6′	5′	5′
Berberis mentorensis	1936	*2′	4′	3′ 6″
Berberis Thunbergii	1936	*15″	3′	3′
Berberis Thunbergii atropurpurea	1936	*15″	3′	3′
Berberis Thunbergii erecta	1936	12–15″	2′ 6″	1′ 6″
Berberis Thunbergii minor	1936	*12–15″	2′	1′ 6″
Berberis vulgaris	1936	*3–4′	3′ 3″	2′ 6″
Berberis vulgaris atropurpurea	1936	*2–3′	3′ 3″	2′ 6″
Buxus microphylla koreana	1936	6–9″	1′ 6″	1′ 3″
Buxus microphylla koreana hybrid	1936	6–9″	1′ 6″	1′ 3″
Carpinus betulus	1936	*18–24″	5′ 3″	6′
Carpinus caroliniana	1936	*4–5′	5′ 3″	6′
Chamaecyparis pisifera filifera	1936	3′	5′ 6″	4′ 6″
Chamaecyparis pisifera plumosa	1936	12–18″	2′ 9″	3′ 3″
Chamaecyparis pisifera squarrosa	1936	2′ 6″-3′	3′ 6″	3′ 6″
Cornus mas	1936	*2–3′	2′ 6″	2′ 6″
Crataegus crus-galli	1936	*2–3′	3′	2′ 9″
Crataegus monogyna	1936	*2–3″	3′ 3″	3′
Crataegus Phaenopyrum	1936	*2–3′	4′	3′
Elaeagnus angustifolia	1936	*18-24″	3′ 6″	3′ 9″
Elaeagnus umbellata	1936	*3′	4′ 9″	4′ 3″
Euonymus alata compacta	1936	*2–3′	3′ 6″	3′ 9″
Fagus grandifolia	1936	*3–4′	2′ 9″	3′
Fagus sylvatica	1936	*6–12″	2′ 6″	2′ 9″
Forsythia intermedia	1936	*18–24″	3′ 9″	3′ 3″
Ligustrum amurense	1936	*6-12″	3′	2′ 6″
Ligustrum ibolium	1936	*18–24″	2′ 9″	2′ 9″
Ligustrum obtusifolium Regelianum	1936	*2′	3′	2′ 6″
Ligustrum ovalifolium	1936	*18″	2′ 9″	2′
Ligustrum vulgare	1936	*2-3′	2′ 9″	2′ 6″
Lonicera fragrantissima	1936	*2–3′	4′ 3″	4′ 6″
Philadelphus coronarius	1936	*2-3′	4′ 9″	4′
Physocarpus opulifolius	1936	*2–3′	5′ 3″	4′ 9″
Picea Abies	1936	3′	4′	4′ 3″
Picea pungens glauca	1936	2–3′	3′ 6″	3′ 3″
Pinus Strobus	1936	18″	3′ 6″	3′
Platanus acerifolia	1936	*2–3′	6′	5′
Prunus tomentosa	1940	*2′	3′ 6″	2′ 9″
Quercus imbricaria	1938	*2′	4′	3′ 9″
Quercus palustris	1936	*6–8′	5′ 9″	5′ 6″
Rhamnus cathartica	1936	*2–3′	3′ 6″	3′
Rhamnus Frangula	1936	*2-3′	3′ 6″	3′
Ribes alpinum	1939	*10″	2′	2′
Spiraea prunifolia	1936	*2–3′	3′	2′ 6″
Spiraea Thunbergii	1936	*2–3′	2′ 3″	2′ 6″
Syringa vulgaris	1936	*2–3′	3′	3′
Taxus canadensis stricta	1936	8–10″	1′ 3″	1′ 6″
Taxus cuspidata	1936	15–18″	2′ 3″	2′ 6″
Taxus cuspidata "capitata"	1936	15–18″	2′ 6″	2′ 6″
Taxus cuspidata nana	1936	12–15″	1′ 6″	2′ 3″
Taxus media (hedge form)	1936	18–24″	2′	2′
Taxus media Hatfieldii	1936	18–24″	2′	2′
Taxus media Hicksii	1936	2–3′	2′	2′ 6″
Thuja occidentalis	1936	2′	3′	2′ 3″
Thuja occidentalis globosa	1936	18″	2′ 6″	2′ 3″
Thuja occidentalis robusta	1936	2′–2′ 6″	3′	2′ 6″
Thuja occidentalis "Little Gem"	1938	6–9″	1′ 6″	2′ 6″
Thuja plicata	1936	9–12″	3′ 3″	2′
Tilia cordata	1936	9–12″	6′	6′
Tsuga canadensis	1939	18″	3′ 3″	2′ 9″
Tsuga caroliniana	1936	18″	3′	2′ 9″
Viburnum dentatum	1936	*2–3′	3′ 3″	2′ 9″
Viburnum prunifolium	1936	*2–3′	3′ 3″	3′

been recently planted, are still too small to be judged properly at this time.

The chief object in this demonstration plot has been to keep all the hedges comparatively low, to give them identical care, and to keep them sufficiently restrained so that they can be clipped easily by a man standing on the ground. This is comparatively easy with *Taxus* species; not so easy with the more vigorous growing *Acer* species. Minor accidents have occurred to plants here and there in the plot,

LIST II—Hedge Plants — Second Choice

(Note: These are decidedly second choice *at present*, being rather slow in growth or slightly open at the base or both.)

Name	Year Planted	Height of Plants Prior to Planting	Height of Clipped Hedge Dec 1, 1944	Width of Clipped Hedge Dec 1, 1944
Abies concolor	1936	12-15"	4'	3' 6"
Acanthopanax Sieboldianus	1936	*2-3'	3' 9"	2' 6"
Betula populifolia	1936	*4'	3' 9"	3' 6"
Caragana arborescens	1936	*3 4'	3'	2' 9"
Cornus racemosa	1936	*2-3'	2' 6"	2' 3"
Juniperus virginiana	1936	2-3'	3' 6"	2' 9"
Lonicera tartarica	1936	*2 3'	4'	2' 9"
Picea Omorika	1936	12 15"	2' 6"	3' 3"
Picea orientalis	1936	3 6"	2' 9"	2' 2"
Pseudotsuga taxifolia	1936	15"	2' 9"	2' 6"
Salix pentandra	1936	*3'	4' 9"	4'
Spiraea nipponica	1936	*18-24"	3' 9"	3'
Spiraea Vanhouttei	1936	*18 24"	3' 9"	3'
Syringa chinensis	1936	*3 4'	3'	3'
Thuja occidentalis Woodwardii	1936	12 15"	2'	1' 9"
Viburnum Lantana	1936	*2-3'	4'	3' 9"

*Cut to within 6 inches above the ground immediately after transplanting in order to make a hedge which was well branched close to the ground.

LIST III—Plants of as Yet Doubtful Value in Hedges But Which May Prove to be Satisfactory Later

(Note: These are either recently planted and too young as yet to be properly judged, or else there is something wrong with them that would appear to make them inferior to those plants in List I.)

Acer platanoides	Very open at base.
Caragana frutex	Only recently planted.
Chaenomeles lagenaria	Only recently planted.
Hypericum densiflorum	Very open at the base.
Ilex crenata convexa	Only recently planted.
Ilex opaca	Only recently planted.
Pinus nigra	All plants died within three years.
Populus alba pyramidalis	Apparently of too vigorously upright growth habit to be well filled out at the base.
Populus nigra italica	Apparently of too vigorously upright growth habit to be well filled out at the base.
Prinsepia sinensis	Only recently planted.
Prinsepia uniflora	Only recently planted.
Prunus japonica Nakaii	Only recently planted.
Quercus robur fastigiata	Dense at top and open at base. Apparently of too vigorously upright growth habit to be well filled out at the base.
Salix purpurea	Few branches at base. Badly infested with oyster shell scale.
Salix purpurea gracilis	Slight infestation of oyster shell scale but apparently an excellent low hedge.
Syringa Josikaea	This has proved to be a consistently poor grower in our plot for some unknown reason. It should be a vigorous growing shrub.
Thuja occidentalis Wagneriana	Too upright in habit—grows laterally very slowly, hence it has made a poor hedge. If plants had been spaced 18 inches or less apart, it might have proved to be satisfactory.
Ulmus pumila	This should make an excellent hedge. Our plants were poor to begin with and this may be the reason why these have made a very poor hedge up to this time.

but as a whole they have grown well. This report deals only with the amount of growth the different plants have made as clipped hedges under Arnold Arboretum conditions, from the time of planting (1936-37) to the present.

LIST IV—PLANTS WHICH HAVE PROVED TO BE DECIDEDLY INFERIOR AS HEDGES

(Note: These are definitely inferior as low hedges under Arnold Aboretum conditions. Some may have died or been susceptible to a serious pest. There is nothing about their performance to date that would suggest these species be selected for hedges if those in Lists I and II are available.)

Abies Fraseri	Not vigorous enough in growth under our conditions to compete with more strongly growing species.
Cercidiphyllum japonicum	Half of these plants are having a hard time getting started. The other half look as if they are so upright in growth habit that they will be open at the base.
Clethra alnifolia	Very poor growth. Our plants are growing in a very dry soil which is probably the cause for the poor development, for with us this is typically a plant of very wet places At Gloucester, Massachusetts, under more moist growing conditions, this has been clipped and forms a fairly dense hedge.
Deutzia gracilis	Died back repeatedly. Did not make a good hedge.
Ginkgo biloba fastigiata	Does not grow vigorously at the sides, hence makes a poor hedge.
Gleditsia triacanthos	Much too open to compete with other plants as a small hedge.
Hippophae rhamnoides	Very difficult to get established under our conditions. Not to be recommended as hedge material.
Juniperus communis	Parts of plants died after shearing and were unsightly. Had to be removed.
Lonicera Korolkovii floribunda	Apparently very difficult to get this established. This was replanted three different times and finally was given up as too difficult to handle as a hedge.
Maclura pomifera	Does not grow well under our conditions.
Philadelphus coronarius pumilus	Does not make a good hedge.
Pinus Mugo	All dead. Plants became quickly infested with scale and soon died.
Pinus Mugo Mughus	Became severely infested with scale and gradually died out. If scale can be kept under control, this plant should make a very dense, low, flat hedge.
Pinus sylvestris	Two plants died within two years after transplanting. As a hedge, it is not as satisfactory as Pinus Strobus.
Rosa rugosa	Became severely infested with a twig borer which ruined the plants.
Rosa virginiana	Not sufficiently dense for a clipped hedge. Does not compare favorably with others for this purpose.
Spiraea Bumalda	Most of the plants died and the remainder were removed.
Symphoricarpos albus laevigatus	Too loose and open in growth. Not suii ciently dense nor vigorous enough for a clipped hedge.
Tamarix pentandra	Most of plants winter killed badly and had to be removed.
Thuja occidentalis spiralis	Rather open at top and makes a poor hedge for this reason.
Viburnum Opulus nanum	Nine of the ten plants died within three years. These were growing in poor soil but should have proved to be hardy. Another trial in another location should be conducted.

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An Analysis of the Process of Root Formation on Cuttings of a Difficult-to-Root Hibiscus Variety

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During our investigations on the principles of root formation in cuttings, we learned of a white-flowered hibiscus variety[1] which is difficult to root, in contrast to the more common red-flowered *Hibiscus rosa-sinensis* L., which roots with great facility. The occurrence of these two closely related varieties which, nevertheless, show such a contrasting behaviour in ability to form roots, afforded an opportunity for an investigation as to the reasons why the white-flowered variety is a difficult rooter. This analysis is reported because it is felt that the principles elucidated here for hibiscus may find application in root formation on cuttings in general. The physiological aspects of this study have been reported in greater detail elsewhere (6).

Effect of Auxin Alone

In view of the fact that auxin treatments have been shown to improve the root formation of cuttings of many plants, this type of treatment was also applied to White hibiscus. It consisted of dipping the basal end of the cutting for a few seconds in a 50 per cent alcoholic solution containing 2 mg of indolebutyric acid per cc (3). The response to this treatment was poor and hardly significant, as is shown in Fig. 1. This should not be interpreted, however, to show that auxin has no role in the rooting process of the White variety. As will

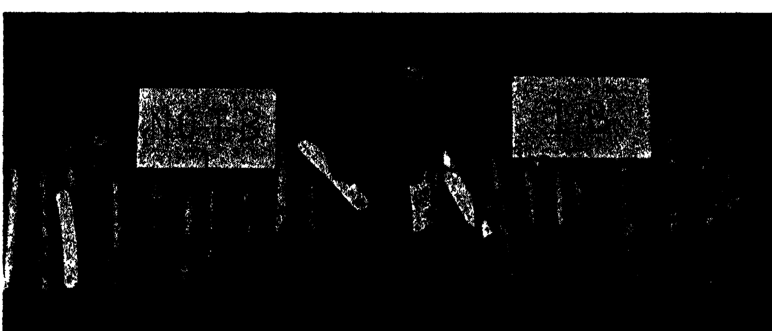

Fig. 1. Cuttings of White hibiscus with (IB) and without auxin treatment. The treatment consisted of dipping the base of the cuttings in an alcoholic solution containing 2 mg per cc of indolebutyric acid, and was given 26 days after the cuttings were made. The latter was done in order to make this experiment comparable to that of Fig. 2. The average number of roots per cutting was 0.3 ± 0.1 for the non-auxin-treated and 3.7 ± 1.4 for the auxin treated series. The temperature of the sand of the propagating frame was approximately 25 degrees C.

[1]The white-flowered variety used in our experiments appears to be *Ruth-Wilcox* (7).

be demonstrated below, auxin is one of the essential factors for root formation, but is needs cofactors before it can exhibit its activity.

Effect of Leaves Alone

White-flowered hibiscus has the tendency to shed its leaves soon after the cuttings are made. The cuttings of the easy-rooting Red hibiscus, by contrast, retain their leaves almost indefinitely. Since, especially through the work of Cooper (1, 2), the importance of leaves for root formation was recognized, attempts were made to compensate for this loss of leaves by grafting Red shoots on White cuttings. This procedure seemed especially desirable because the possibility existed that the easy-rooting Red scion would contribute some factors which might facilitate root formation on the difficult-to-root White stock[2]. However, this grafting procedure by itself did not increase the number of roots formed (Fig. 2, left), just as an auxin treatment by itself is ineffective.

FIG. 2. Shoots of Red hibiscus (R) grafted on cuttings of White hibiscus (W). The base of one series was treated with auxin as indicated under Fig. 1, and 26 days after the grafts were made. The photograph was made 19 days later. The controls, White hibiscus without grafts, but with IB, are shown in Fig. 1. The average number of roots per cutting was 1.1 ± 0.7 for the non-auxin-treated R/W cuttings, and 32.6 ± 3.9 for the auxin treated ones. Rooting takes place only as a result of the combined action of auxin and the Red hibiscus scion.

Interaction of Auxin and Leaves

When, however, the base of the R/W cuttings[2] was treated with auxin, the number of roots was increased from an insignificantly low number to an average of over 30 roots per cutting (Fig. 2, right). This number of roots is not less than that (Fig. 3) produced by the easy-rooting Red variety. The grafting experiments demonstrate clearly that for the rooting of White hibiscus cuttings, two distinct factors are required. Auxin is one factor, but it will function to produce roots only in the presence of an additional factor, or more likely

[2]The combination of a shoot of Red hibiscus bark-grafted on a cutting of the White variety will be referred to hereafter as a R/W cutting.

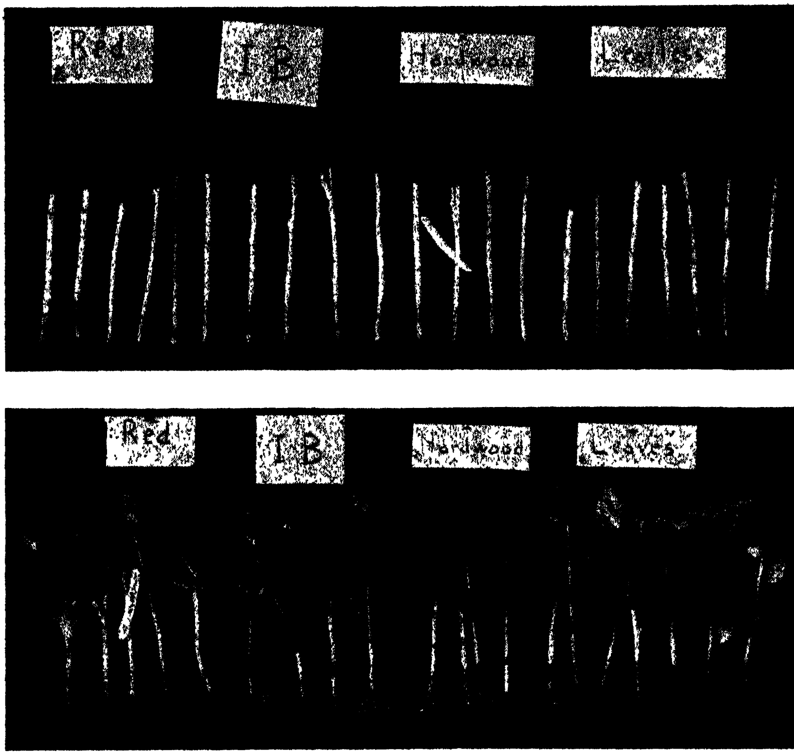

FIG. 3. The effect of leaves on the root formation of auxin treated cuttings of Red Hibiscus. "Hardwood" cuttings which were treated with indolebutyric acid, as indicated under Fig. 1, but immediately after the cuttings were made. The average number of roots was 1.7 ± 1.2 per cutting for the defoliated, and 6.8 ± 1.8 for the leafy cuttings. For thin terminal cuttings ("softwood," not shown) the comparable figures were 0 and 17.5 ± 2.1. Observations after 17 days. Averages of 20 cuttings.

a complex of factors, which is contributed by the shoots of Red hibiscus.

The leaves of Red hibiscus are the principal source of this second factor, which is conducted through the bark to the base of the White cutting (6). Furthermore, it has been shown (6) that the factor will move sidewise through the bark with facility, hence, its transport is not rectilinear only.

"Hardwood" cuttings of the Red hibiscus variety, without grafting, showed the same interaction between auxin and leaves as the R/W cuttings of Fig. 2. Defoliated "hardwood" cuttings produced only an average of 1.7 ± 1.2 roots per cutting after auxin treatment, while similar leafy cuttings produced an average of 6.8 ± 1.8 roots per cutting (Fig. 3). The fact that defoliated cuttings produced any roots at all might be attributed to reserves of the factor stored in the cuttings. A point in favor of this assumption is that defoliated cuttings

taken from thin terminal branches produced practically no roots even when treated with auxin. For instance, in the series of which the cuttings of Fig. 3 were part, only a total of one root was produced in the whole series of 20 thin cuttings, while comparable cuttings with their leaves retained produced an average of 17.5 roots per cutting (see legend of Fig. 3).

In practice it is known that leafless cuttings of some plants can be rooted with facility. This is not necessarily a contradiction to the conclusion that substances produced in the leaves are necessary (together with auxin) for root formation. These substances may be stored in the cuttings of certain plants and may act long after the leaves have gone.

Effect of Early Loss of Leaves and Its Partial Responsibility for Difficult Rooting

In view of the above mentioned experiments which demonstrated that the presence of leaves is essential for good rooting, attempts were made to prevent the early shedding of leaves from the White hibiscus cuttings. In some experiments the leaves were sprayed with dilute auxin solutions in attempts to delay abscission (for literature see 5). In other experiments calcium propionate[3] was applied in an attempt to prevent molding (4). Both treatments failed to halt the early abscission and deterioration of the leaves on the cuttings of the White variety. It was found that at times,[4] however, White cuttings would retain many of their leaves. In such cases, a considerable number of roots would be produced, but again, as with the R/W cuttings, only after the base of the cuttings had been treated with auxin. Fig. 4 shows this for "hardwood" cuttings.

Although one may be tempted to attribute the poor rooting qualities of White hibiscus cuttings entirely to this early and spontaneous defoliation, further research has shown that this is not the case. Fig. 5 shows a series of terminal cuttings of White hibiscus which retained their leaves exceptionally well. When treated with auxin, these White cuttings produced roots, but at a slower rate and in smaller numbers than comparable cuttings of the Red variety. This shows that even though White cuttings retain their leaves, they still are more difficult to root than cuttings of the Red hibiscus.

Rooting of Detached Leaves

Roots may be induced on detached hibiscus leaves with, as well as without, petioles. As a rule, more roots are formed after treatment with auxin (Fig. 6). In comparing the root formation on detached leaves of both hibiscus varieties, it was found that leaves of Red hibiscus produced many more roots than those of the White variety. While in the Red variety 80 per cent of the leaves formed roots, in

[3]Preparation known as Mycoban was used which was kindly supplied by the Dupont Company.

[4]Retention of leaves and responses to IB seemed improved during the winter season.

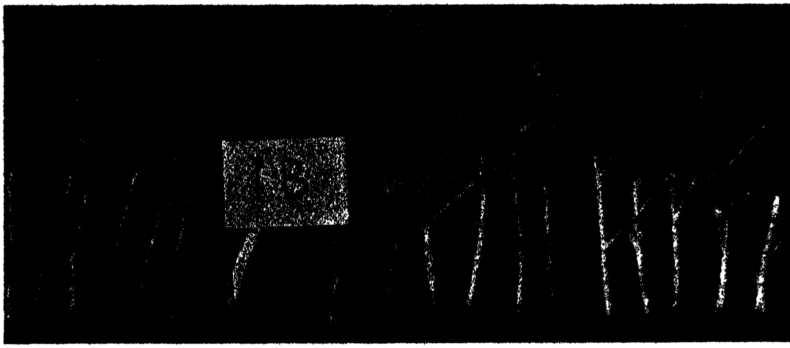

FIG. 4. Root formation on auxin-treated "hardwood" cuttings of the white-flowered hibiscus, on which the leaves happened to stay on longer than usual. Fourteen out of nineteen cuttings produced an average of 8.3 ± 2.0 roots per cutting (average of 19 cuttings: 6.1 ± 1.7). In the non-auxin-treated series (not shown) only 2 out of 20 cuttings rooted, each having one small root. Auxin treatments and conditions of propagation as under Fig. 3. Observations after 29 days.

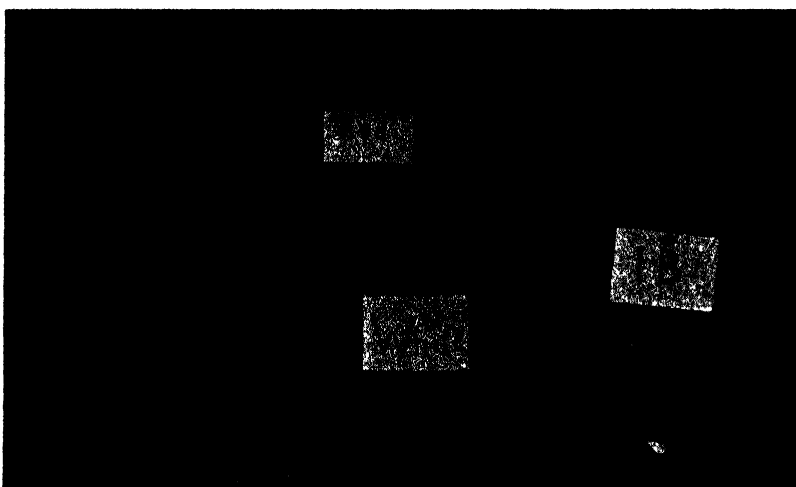

FIG. 5. Comparison in root formation on terminal shoots or Red and White hibiscus. The average number of roots per 20 cuttings was for the series which was treated with auxin: 6.2 ± 1.2 for the Red, and 2.1 ± 0.6 for the White. Observations were made 20 days after treatment, which consisted of dipping the base of the cuttings in an alcohol solution containing 2 mg/cc of indolebutyric acid. The average number of roots per 20 cuttings in the non-treated series (not shown) was 3.2 ± 0.8 for the Red and 1.1 ± 0.3 for the White. As in Fig. 4, the retention of leaves on the White cuttings is an exception, rather than the rule.

the White variety only one single root was formed as the result of trials on some 50 leaves.

Since the experiments with auxin-treated R/W cuttings show that

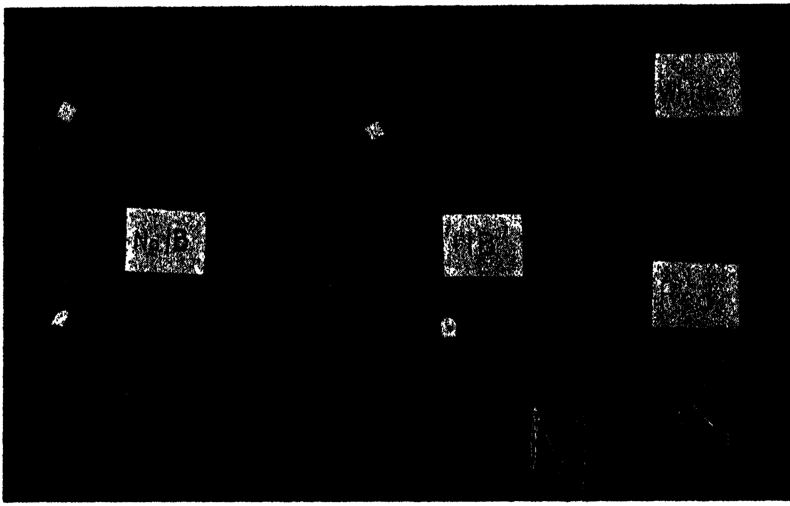

FIG. 6. Root formation on detached laminae of leaves of Red and White hibiscus. The average number of roots formed in 21 days on Red leaves was 6.0 for the auxin treated and 2.3 for the non-treated controls. No roots were produced on the White laminae. Temperature of the sand in which the root formation took place: 30 degrees C.

White cuttings are capable of producing a number of roots which is comparable to that produced on Red cuttings, it does not seem likely that the poor root formation on leaves of White hibiscus is to be attributed to some morphological characteristic which make the tissue of the White variety less suitable for root formation than that of the Red variety. It may be, therefore, that detached leaves of White hibiscus root poorly because they contain a smaller effective amount of the substance (or substances) which is (are) necessary, together with auxin, to produce roots. This lower effectiveness of its leaves must be another reason which makes White hibiscus a plant which is difficult to propagate by means of cuttings.

CONCLUSIONS

The experiments discussed above and elsewhere (6) demonstrate that for the rooting of cuttings of the common Red hibiscus as well as the white-flowered variety, two distinct factors ,are necessary. These factors which have to act coordinately (they are inactive by themselves) are: (a) auxin and (b) a substance (or substances) produced by leaves.

The cuttings of the White variety are difficult to root because: (a) they are deficient in auxin, (b) they are deficient in the factor (or factors) which is (are) produced by leaves. When both factors are provided, this difficult variety has been shown to produce roots readily.

The reasons for the deficiency of the second factor are: (a) an early shedding of the leaves from the cuttings of White hibiscus, and (b) a lower effective content of the factor (s) in the leaves of the White than in the leaves of Red hibiscus, as was indicated by a difference in root formation on detached leaves of both varieties.

The chemical nature of the root-forming substance (or substances) produced by the leaves is under investigation at present. Preliminary experiments seem to indicate that they are, at least in part, substances which may be classified as nutritional factors. However, the possibility is not excluded that hormonal factors, other than auxin, may also be involved.

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